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Mars Rover Base Station: System Manual

AN OVERVIEW OF THE COMMUNICATIONS BASE STATION FOR THE RASC-AL ROBO-OPS MARS ROVER

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Abstract

The Mars Rover Base Station aims to assist the West Virginia University Robotics team with NASA's RASC-AL Robo-Ops Mars Rover competition. Only eight teams are selected nationally for the competition, and WVU has been lucky enough to be among those eight this year, along with the previous two. In the past, WVU has only been able to achieve a highest ranking of fourth place in the competition, partially due to communications issues. The Base Station aims to resolve many of these issues that have plagued the team in the past. Since the competition takes place in Houston, TX, but the rover must be piloted from the Engineering Research Building in Morgantown, communications play a key role in the success of the team during the competition.

To begin the competition, the rover is placed on top of a hill in the midst of a "Mars-like environment." The pilots then have one hour to traverse the competition field, the "Rock Yard," in search of "Space Rocks." These Space Rocks, which are simply brightly painted rocks of differing shapes and sizes, serve as the scoring opportunities for the competition. The pilots must drive the rover, find these rocks, pick them up, and place them in an on-board bin to obtain points for the competition.

During the 2013 competition last June, the pilots were, at times, driving blindly. When a picture was available, it was often delayed by anywhere from thirty to sixty seconds, making it nearly impossible to drive effectively. The reason behind this was a poor internet signal within the Rock Yard. The Base Station will begin as a small, compact system that will be deployed from underneath the rover at the starting location. Once the rover begins to drive towards the Rock Yard, the Base Station will expand and position an omnidirectional antenna roughly two meters above the ground. The system will receive a 4G cellular data signal from Verizon, and transmit a wireless internet signal across the competition field. A Virtual Private Network will be initialized between the Base Station, the rover, and the Robotics servers at WVU for fast and secure transferring of all data and video.

Introduction

Mars is now the planet that interests space-related organizations like NASA the most. Due to the distance, dangers, and the unknowns on Mars, exploring the planet is not a task that astronauts can or will take. Robots have taken over this job for the foreseeable future. The Several Mars Rovers have been designed and traveled to Mars to gather as much information as possible. Since the investment and labor is so intensive to send one of these machines the great distance to Mars, the design must be flawless and not incur any malfunctions throughout any difficult situation that it may encounter in its lifetime. A well-functioning rover should be able to travel on Mars, analyze the surroundings and transmit data back to the Earth.

RASC-AL Exploration Robo-Ops Competition is a NASA sponsored competition that is held in Houston, Texas every year. Eight universities are to be chosen from all applicants to participate in the competition. Each school is required to design and build their own version of the Mars Rover. Certain restrictions are applied to the design of the Mars Rover. Its dimensions cannot exceed 1m x 1m x 0.5m and the whole device must weigh less than 45 kilograms. All add-ons to the robot are included in the dimension and weight restriction. The rover should be able to traverse over obstacles up to 10 cm in height, negotiate upslopes and downslopes up to a 33% grade and travel through sand, gravel, rocks, and craters. The course is built to simulate the possible terrains on Mars. The main way for scoring points in the competition is by locating "space rocks," oddly shaped rocks that have been brightly painted, and collecting them in an on-board bin.

In order to simulate the circumstance of the rover being controlled remotely from earth, the pilot of each rover in the competition will be controlling the rover from his or her home university. Without communicating with teammates in Houston, the pilot needs to locate the colored rocks, travel to them, and collect and place the rocks in the bin. There are six different colors, with each color having a different assigned point value. The winner will be determined by how many colored rocks, and the total point value of the rocks, that the rover brings back. The team with the highest point total will take home first place in the performance section of the competition. Violating any rules of the competition will result in a point penalty and a disadvantageous spot in the starting order.

The goal of NASA by sponsoring the RASC-AL Exploration Robo-Ops competition is "to engage as many people as possible in space exploration missions." Therefore, each team is required to partner with public organizations while they are working on the rover. This outreach makes up a portion of the competition, and the teams with the most outreach hours will achieve a high score in this section.

The West Virginia University robotics team is one of the eight teams that have been chosen to participate in the competition, the third straight year for the team. Although the team is relatively new to the competition, designs in previous years have proven the WVU students are more than capable of producing a competition-worthy robot. In 2012, the team's first trip to Houston, the team finished in fourth place overall. With the improvements made after the 2012 competition, the team still did not manage to win first place the following year. The major problems in the 2013 competition were with the communications. The video feeds sent to the pilot from the rover's on-board cameras were grainy and had a delay that ranged from three to fifteen seconds. This increased the difficulty for pilot to control the robot on the field, or as the NASA officials refer to it, the "Rock Yard." This design included the communications being handled by a Verizon 3G/4G wireless card. The rover couldn't communicate with the pilot effectively because the cellular signal that reached the rover was not strong enough to handle data compression and transmission.

Therefore, the main goal for this year's competition will be to improve the communication systems. Since the rover will start at the highest point of the course in the competition, a base station will be placed at the starting location. The base station will be used as a relay station between the pilot and the rover. It will receive the commands from the pilot through cellular network and communicate with the rover over a 3G/4G integrated router. On top of the base station, a camera will be installed to help guide the pilot, locate the rover, and search for the colored rocks. A user interface is to be developed that will allow the pilot to choose the function of the camera and display the appropriate data. It will be designed to let the pilot see different camera feeds and switch between camera feeds easily.

The following sections will show more details of the problem, how the robotics team will achieve these goals, the actual design of the base station, test plans and project management plan.

2.0 Design Achievements

So far, the group has finished the bandwidth tests for the base station. The base station will be used, as expected, as the relay station between the pilot at WVU and the rover down in Houston, Texas. The camera mounted on top of the base station will provide an overview view for pilot to locate the colored rocks and the rover.

Since none of the group members had experience on machining, all of the group members learned how to use different machines to make the parts that are needed for building the base station, such as the lathe, mill, and many others. Group members also gained knowledge about materials that are commonly used in robotics.

Group members have participated and helped in various robotics outreach events, such as girl's scouts day, 8th grade day and Lego League. One of the most important outreach events was the Tekids. Tekids is a program designed to introduce STEM field to elementary school students. With hands-on experiences, the kids could develop an interest in STEM field. Tekids lasted for 8 weeks, 4 days a week. Group members watched kids while they attempted to complete the project and made sure they do it safely. Group members also helped teach the

kids when they couldn't understand the concepts. With very few teachers presented in the events, the assist of group members had become very helpful.

In order to prove the concept of the base station design, a prototype has been built. The camera mount, and the box for battery and raspberry pi were built from scratch by group members. With the cylinder and the pulley system, the base station can deploy itself and raise the camera to up to 1.5 meters high. At the same time, the base station fits underneath the rover before it is deployed which satisfied the dimension restrictions.

Currently, not all the needed parts hve arrived. Additionally, the materials of some parts are still under debate due to the weight restrictions. An actual product has not been built due to reasons above. Once the parts arrive and materials are decided, the production of the finished product is estimated to take 1-2 days.

3.0 Hardware Design

Overview

The hardware included in the Base Station is a simple set-up that makes use of fundamental mechanical devices: a gas charged cylinder, a system of pulleys, and a hinge. Most electronics are contained as part of an enclosure that is made up of an 8 in x 6 in aluminum box and lid. Cuts have been made in the box to increase ventilation for the electronics, and mounts have been created to house the electronics. On top of the lid, a CradlePoint IBR600 has been mounted with all antennas extending upward. An 8,000 mAh LiPo battery and a Raspberry Pi are mounted inside of the enclosure. The Raspberry Pi controls a mounted DC Motor, solenoid, and switches.

The mast is made up of two carbon fiber tubers that have been cut so that, when fully extended, the top of the mast will be over 1.5 meters off of the ground. To lock these sections into place during extension, a snap lock, which was printed using the department's three-dimensional printer, will protrude from the top section once a certain length is above the bottom section. Attached inside of the top section is a mount for a Panasonic iPro networking camera. The bottom of section of the mast is pivoted around a bracket that is mounted to a platform that is constructed from carbon board. An aluminum air-flow cylinder, pressurized to nearly 75 psi, compresses and decompresses to pivot the mast around this bracket. Once the cylinder has raised the bottom module of the mast, the rover will move forward and stop on the cross-section of the platform. On this cross-section lie switches,which will activate a solenoid to allow the cylinder to lift the mast vertically. Once the mast is fully raised, a DC motor will be used to crank a pulley system to raise the top section of the arm to its full height.

The bottom of the enclosure and the brackets for the mast are attached to the carbon board platform which will sit flatly on the ground. This platform will extend the length of the rover, allowing the rover's wheels to rest on the edges of the platform. As the rover drives away, the cylinder will begin to rise. The platform allows the weight of the robot to hold down the system as the mast is rising, keeping the center of gravity low, and preventing any tipping of the system that could occur. Please reference the Solidworks drawings below for a visual reference of the original design. The only difference in this original design and the finalized design are that the enclosure no longer supports the mast on its lid. The mast is now a separate entity within the system. The final structural design is also below.

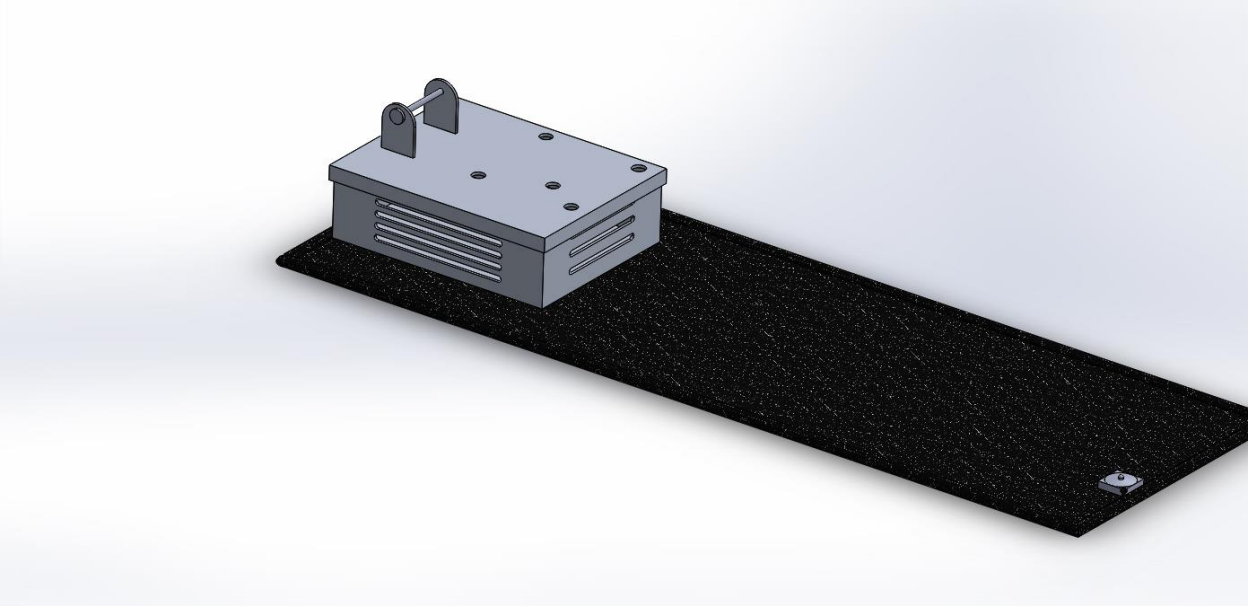

Figure 1: Enclosure and Platform

Figure 2: Extended System

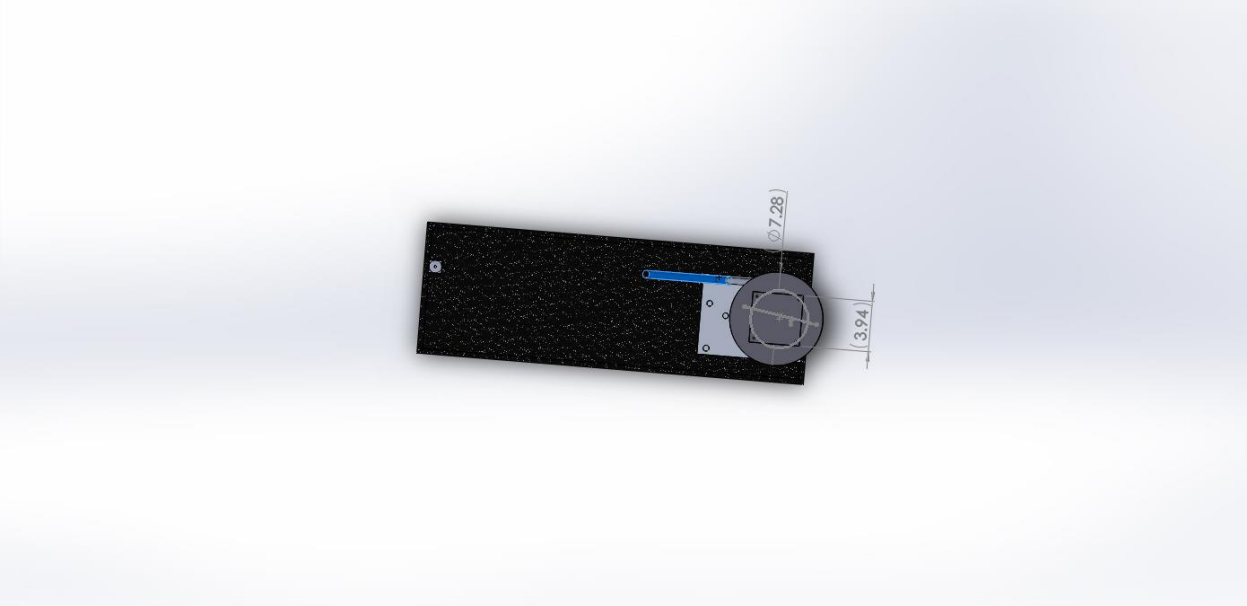

Figure 3: Base Station View from Above

Figure 4: Final Structural Layout

List of Materials

Materials	Purpose
Aluminum	Mast, Enclosure, Lid
Carbon Board	Platform
Air Cylinder	Raising/Lowering Mast
Pulley Wheel	Extending Top Section
Kevlar String	Extending Top Section
CradlePoint IBR600	Communications
Raspberry Pi	Initializing VPN, Operating Peripherals
Panasonic iPro WV-SC386	Video Support for Rover
PWM Servo	Beginning Process
DC Motor	Extending Top Section
Limit Switches	Timing
8000 mAh LiPo Battery	Powering Components

Product Spec Sheets

1. CradlePoint IBR600

cradlepoint.com/cor

COR IBR600/IBR650 Integrated Broadband Router

Internet Access and Device Connectivity

- Includes integrated 3G/4G modem (see attached for options and specifications)
- 2 Ethernet LAN/WAN ports for Ethernet-enabled devices or landline Internet
- Wireless 2x2 MIMO "N" WiFi (802.11 b/g/n)*
- Supports up to 64 WiFi connections at a time*
- Two SSIDs (with individual security, bandwidth limits, and QoS settings; separate critical traffic or create a public WiFi hotspot)*

Security

- IPsec VPN (up to 5 concurrent sessions) and GRE Tunneling option, also supports passthrough VPN connections (IPsec, L2TP, PPTP)
- Layer 2 Tunneling Protocol (L2TP)**
- WEP, WPA, WPA2, WPA2 Enterprise with AES encryption for secure WiFi*
- 802.1Q VLAN support to isolate, segment and secure network traffic
- SPI (stateful packet inspection) firewall and NAT (network address translation) to prevent unwanted access to connected computers
- Variety of security features (URL filtering, IP & traffic filtering, DMZ, port forwarding) for safer Internet access
- Advanced security mode and reporting to facilitate PCI-DSS compliance

Flexibility

- First-time and advanced setup wizards for easy, swift, and secure setup
- Remote management with CradlePoint Enterprise Cloud Manager
- SNMP v1/2c/3, CLI over SSH, and SMS
- IP passthrough support provides 3G/4G-to-Ethernet adapter
- Create a WiFi hotspot with a captive portal (terms of service, ads, etc)*
- Network failover support & load balancing
- GPIO for additional hardware control, serial console available (USB-to-serial)
- LAN/WAN affinity to assign specific LAN traffic to a WAN
- Enterprise routing protocols:** BGP, OSPF, RIP
- VRRP for enterprise router redundancy**
- GPS NMEA GGA, VGT, and/or RMC sentence support
- IPv6 support
- Advanced APN management
- Network Mobility (NEMO) support for session continuity in mobile networks**
- Roaming control and ability to force 3G or 4G bands

Service, Support, and Warranty

- CradleCare Support Agreement with technical support, software upgrades, and advanced hardware exchange – 1, 3, and 5 year options
- Limited 1 year warranty included with hardware repair or replacement – extend warranty to 2, 3, or 5 years
- CradleCare Site Survey and Installation services offered for rapid deployment

IBR600/IBR650 Differences

- IBR600: Includes WiFi, hotspot services/captive portal, WiFi as WAN
- IBR650: WiFi excluded in order to facilitate PCI and HIPAA compliance

**WiFi-related items are only supported on IBR600 models*
***Requires an Extended Enterprise License*

Specifications

WAN Integrated modem, 10/100 Ethernet port, WiFi as WAN*
LAN WiFi (802.11 b/g/n)*, two 10/100 Ethernet ports (WAN or LAN)

TEMPERATURE −20°C to 60°C (−4°F to 140°F) operating modem as WAN
−20°C to 50°C (−4°F to 122°F) operating Ethernet as WAN
−30°C to 70°C (−22°F to 158°F) storage

RELATIVE HUMIDITY (non-condensing) 10% to 85%, operating
5% to 90%, storage

POWER DC input steady state voltage range: 9 – 18VDC
Recommended inline fuse for vehicle installations: 1.5A fast-blow (see vehicle best practices installation guide for details)

WIFI* (IBR600) Transmit power: 15 dBm typical for all modes; receive sensitivity: −68 dBm @HT20 (11n), −65 dBm @HT40 (11n), −72 dBm typical @54 Mbps (11g), −84 dBm typical @11 Mbps (11b); antennas: 5 dBi gain

SIZE 3.3-in x 4-in x 0.9-in (85mm x 102mm x 22mm)
WEIGHT 7.2 oz (200g)

CERTIFICATIONS FCC, WiFi Alliance*, Shock/Vibration (MIL STD 810G and SAEJ1455), carrier certifications (see individual SKUs for additional certifications)

What's In The Box

- COR IBR600/IBR650 Integrated Broadband Router w/ metal mounting bracket
- External 3G/4G mobile broadband modem antennas (2) (SMA) w/ support for GPS on auxiliary connection (some models), finger tighten only
- External WiFi antennas (2) reverse SMA*, 5 dBi gain, finger tighten only
- 12V / 1.5A power supply w/ locking connector; GPIO/power cable available
- Quick Start Guide with warranty information

Accessories

High-gain external antennas (Omni-directional, Patch, Yagi, 12" Mag-mount, 4" Mini mag-mount), GPIO/power cable, see cradlepoint.com/COR for more

Requirements

Internet Service and Modem Active mobile broadband plan with cellular provider or Ethernet-based Internet connection (DSL, cable, satellite, T1)

Browser (to configure router) Minimum of Firefox v2.0, Internet Explorer v7.0, Chrome, or Safari v1.0

Router Details

Security NAT, SPI, ALG, inbound filtering of IP addresses, port blocking, service filtering (FTP, SMTP, HTTP, RPL, SNMP, DNS, ICMP, NNTP, POP3, SSH), protocol filtering, WAN ping (allow/ignore), 802.1X Ethernet port security

Redundancy and Load Balancing Failover/failback with 4G, 3G, Ethernet with rule selection, advanced load balancing options (round robin, spillover, data usage, rate), WAN failure detection, VRRP**

Intelligent Routing UPnP, DMZ, virtual server/port forwarding, routing rules, NAT-less routing, wired or wireless WAN-to-LAN IP passthrough, route management, per-interface routing, content filtering, IP filtering, website filtering, per-client Web filtering, local DHCP server, DHCP client, DHCP relay, DNS, DNS proxy; ALGs: PPTP, L2TP, PPPoE passthrough, IPsec passthrough, FTP (passive), FTP (active), SIP, TFTP, IRC, MAC address filtering, Dynamic DNS, LAN/WAN affinity, VLAN support (802.1Q), STP, enterprise routing protocols: BGP/OSPF/RIP, multicast proxy support, IP setting overrides, Network Mobility (NEMO)**, IPv6

Management CradlePoint Enterprise Cloud Manager (subscription-based); web-based GUI (local management); optional RADIUS or TACACS+ username/password; remote WAN web-based management w/access control (HTTP, HTTPS); SNMP v1, v2c, & v3; CLI over SSH, SSH to serial, SSH to telnet; API; one-button firmware upgrade; modem configuration, update, and management; modem data usage w/ alerts, per-client data usage; custom AT scripting to modems; SMS

Performance & Health Monitoring WiPipe™ advanced QoS with traffic shaping, Modem Health Management (MHM) improves connectivity of modem, SSID-based priority, WAN port speed control, several levels of basic and advanced logging for troubleshooting

VPN (IPsec) Tunnel, NAT-T, and transport modes; connect to CradlePoint, Cisco/Linksys, CheckPoint, Watchguard, Juniper, SonicWall, Adtran, etc.; certificate support; Hash (MD5, SHA128, SHA256, SHA384, SHA512), Cipher (AES, 3DES, DES), support for 5 concurrent connections, GRE tunneling, multiple networks supported in a single tunnel, site-to-site dynamic VPN with NHRP**, L2TP**

GPS Active standalone GPS on -PWD models, passive standalone GPS on others; GUI mapping as well as local (LAN) or remote (WAN) server logging; NMEA GGA, VGT, and/or RMC sentence support

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One-year limited hardware warranty available in the US and Canada; two-year limited hardware warranty for integrated EU products when purchased from an authorized EU distributor. Product specifications are subject to change without notice, and product appearance may differ from image depicted in this document. This product requires either an active subscription from a wireless service provider or an Ethernet-based broadband service from an Internet service provider to receive Internet service. Check with your broadband provider for service coverage, fees, and other charges. © 2014 CradlePoint, Inc. All rights reserved. CradlePoint, WiPipe™, and the WiPipe logo are trademarks of CradlePoint, Inc. in the US and other countries. Other trademarks are the property of their respective owners.

2. Panasonic iPro WV-SC386

Specifications

TV System			NTSC	PAL
Camera	Image Sensor		1/4 type MOS Sensor	
	Effective Pixels		Approx. 1.3 megapixel	
	Scanning Mode		Progressive scan	
	Scanning Area		3.6 mm (H) x 2.7 mm (V) (5/32 inches (H) × 11/100 inches (V))	
	Minimum Illumination		Color: 0.5 lx, B/W: 0.06 lx at F1.4 (Shutter: 1/30 s, AGC: High), Color: 0.031 lx, B/W: 0.004 lx at F1.4 (Shutter: 16/30 s, AGC: High)	
	White Balance		AWC (2,000 ~ 10,000 K), ATW1 (2,700 ~ 6,000 K), ATW2 (2,000 ~ 6,000 K)	
	Light Control Mode		Indoor scene (50 Hz / 60 Hz) / Outdoor scene / Fix shutter	
	Shutter Speed		Fix shutter: OFF (1/30), 3/100, 3/120, 2/100, 2/120, 1/100,1/120, 1/250, 1/500, 1/1,000, 1/2,000, 1/4,000, 1/10,000	
	Super Dynamic		ON / OFF	
	Face Super Dynamic		ON / OFF (Only at Super Dynamic: ON)	
	Dynamic Range		52 dB typical (Super Dynamic: ON, Light Control mode: Indoor)	
	Adaptive Black Stretch		ON / OFF	
	AGC		ON (LOW, MID, HIGH) / OFF	
	Electronic Sensitivity UP		OFF, max. 2/30 s, max. 4/30 s, max. 6/30 s, max. 10/30 s, max. 16/30 s	
	Black and White Mode		Mode: AUTO1 / AUTO2 / AUTO3 / ON / OFF	
	Digital Noise Reduction		High / Low	
	Video Motion Detection		4 areas, Sensitivity: 15 steps, Detection size: 10 steps	
	Privacy Zone		Up to 8 zones, Gray / Mosaic	
	Auto Image Stabilizer		ON / OFF	
	Camera Title (OSD)		Up to 20 alphanumeric characters (3 selectable character sizes)	
Lens	Focal Length		3.3 mm ~ 119 mm	
	Zoom Ratio		36x / 72x with extra optical zoom (at VGA)	
	Digital (Electronic) Zoom		12x (Max. 864x combined with extra optical zoom at VGA)	
	Angular Field of View		H: 1.7° (Tele) ~ 60.2° (Wide), V: 1.3° (Tele) ~ 46.0° (Wide)	
	Maximum Aperture Ratio		1 : 1.4 (Wide) ~ 4.8 (Tele)	
	Focusing Range		2.0 m ~ ∞	
	Aperture Range		F1.4 ~ 22, Close	
Pan and Tilt	Panning Range		360° endless	
	Panning Speed		Manual: approx. 0.065°/s ~ 120°/s, Up to 256 steps (depending on the controller) Preset: up to approx. 400°/s	
	Tilting Range		−15° ~ 185° (upward-level-downward) Tilting angle limit: 10° / 5° / 3° / 0° / −3° / −5° / −10° / −15°	
	Tilting Speed		Manual: approx.0.065°/s ~ 120°/s, Up to 256 steps (depending on the controller) Preset: up to approx. 400°/s	
	Proportional Pan/Tilt Control		Yes	
	Number of Preset Positions		256	
	Auto Mode		preset sequence / auto pan / auto track / patrol	
	Image Hold		ON / OFF	
	PTZ Position Display		ON / OFF	
	Self Return		10 s / 20 s / 30 s / 1 min / 2 min / 3 min / 5 min / 10 min / 20 min / 30 min / 60 min	
	Map Shot		360° map shot / preset map shot	
Browser GUI	Camera Control		Pan/Tilt (16 steps), Zoom, Focus, Click centering, Drag zoom, Iris, Preset position call and program, Auto mode	
	Display Mode		Spot, Quad: Image from 16 cameras can be displayed in 4 different Quad screens or 16 split screen (JPEG only), 20 characters camera title available.	
	Camera Title		Up to 20 alphanumeric characters	
	Clock Display		Time: 12H / 24H, Date: 5 formats on the browser, Summer time (Manual/AUTO)	
	Alarm Control		Reset	
	One Shot Capture		A still picture will be displayed on a newly opened window.	
	Audio		Mic (Line) Input: ON / OFF Volume adjustment: Low / Middle / High, Audio Output: ON / OFF Volume adjustment: Low / Middle / High	
	SD Memory Data Download		Still or motion images recorded in the SDHC/SD memory card can be downloaded.	
	GUI/Setup Menu Language		English, French (Installation required for French)	English, French, Italian, Spanish, German, Russian (Installation required except for English)
	System Log		Up to 100 (Internal), Up to 4,000 (SDHC/SD memory when the recording format is set to JPEG.) error logs	
	Supported OS *1 *2 *3		Microsoft® Windows® 8, Microsoft® Windows® 7 Microsoft® Windows Vista®, Microsoft® Windows® XP SP3	
	Supported Browser		Windows® Internet Explorer® 10.0 (32 bit) Windows® Internet Explorer® 9.0 (32 bit) Windows® Internet Explorer® 8.0 (32 bit) Windows® Internet Explorer® 7.0 (32 bit) Microsoft® Internet Explorer® 6.0 SP3	
Network	Network IF		10Base-T / 100Base-TX, RJ-45 connector	
	Image Resolution *4 *5	Aspect ratio: [4 : 3]	H.264: 1,280 × 960 / 800 × 600 / VGA (640 × 480) / QVGA (320 × 240), up to 30 fps MPEG-4: VGA (640 × 480) / QVGA (320 × 240), up to 30 fps JPEG (MJPEG): 1,280 × 960 / 800 × 600 / VGA (640 × 480) / QVGA (320 × 240), up to 30 fps	
		Aspect ratio: [16 : 9]	H.264: 1,280 × 720 / 640 × 360 / 320 × 180, up to 30 fps JPEG (MJPEG): 1,280 × 720 / 640 × 360 / 320 × 180, up to 30 fps	
	H.264/ MPEG-4 *4	Transmission Mode	Constant bitrate / Framerate priority / Best effort / Advanced VBR	
		Frame Rate	1 / 3 / 5 / 7.5 / 10 / 12 / 15 / 20 / 30 fps	
		Bit Rate/Client	64 / 128 / 256 / 384 / 512 / 768 / 1,024 / 1,536 / 2,048 / 3,072 / 4,096 / 8,192* kbps / Unlimited *H.264 mode only	
		Image Quality	LOW / NORMAL / FINE	
		Refresh Interval	0.2 s / 0.25 s / 0.33 s / 0.5 s / 1 s / 2 s / 3 s / 4 s / 5 s	
		Transmission Type	UNICAST / MULTICAST	
	JPEG (MJPEG)	Image Quality	10 steps	
		Transmission Type	PULL / PUSH	
	Audio Compression		G.726 (ADPCM) 32 kbps / 16 kbps, G.711 64 kbps	
	Audio Mode		OFF / Mic (Line) input / Audio output / Interactive (Half duplex) / Interactive (Full duplex)	
	Authentication for Audio		Level 1 only / Level 2 higher / All users	
	Total Bit Rate		64 / 128 / 256 / 384 / 512 / 768 / 1,024 / 2,048 / 4,096 / 8,192 kbps / Unlimited	
	Supported Protocol		IPv6: TCP/IP, UDP/IP, HTTP, HTTPS, RTP, FTP, SMTP, DNS, NTP, SNMP, DHCPv6 IPv4: TCP/IP, UDP/IP, HTTP, HTTPS, RTSP, RTP, RTP/RTCP,FTP, SMTP, DHCP, DNS, DDNS, NTP, SNMP, UPnP	

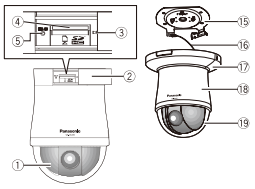
• All TV pictures are simulated. • Masses and dimensions are approximate.
• Specifications are subject to change without notice.
• These products may be subject to export control regulations. • All product pictures are NTSC models.

TV System		NTSC	PAL
Network	FTP Client	Alarm image transfer, Periodic image transfer (When the FTP periodic transmission is failed, backup on an optional SDHC/SD memory card is available.)	
	No. of Simultaneous Users	Up to 14 users (Depends on network conditions)	
	SDHC/SD Memory Card (Option)	H.264 recording: Manual REC / Alarm REC (Pre/Post) / Schedule REC JPEG recording: Manual REC / Alarm REC (Post) / Backup upon network failure Compatible SD (SDHC) card: Panasonic 256 MB, 512 MB, 1 GB, 2 GB, 4 GB*, 8 GB*, 16 GB*, 32 GB* model * SDHC card	
	Cellular Phone Compatibility	JPEG image, panning/tilting/zoom control, AUX control (by access level)	
Alarm	Alarm Source	3x Terminal inputs, VMD, Command alarm , Auto track	
	Alarm Actions	SD memory recording, E-mail notification, Indication on browser, Camera positioning, Preset position 1 ~ 64, FTP image transfer, Terminal output, Panasonic protocol output, Auto track	
	Alarm Log	With SD memory card: 5,000 logs, Without SD memory card: 1,000 logs	
	Schedule	Alarm/VMD/Access permission, Preset position call, Position refresh, H.264 recording	
Input / Output	Monitor Output (for adjustment)	1.0 V [P-P] / 75 Ω, NTSC composite, BNC	1.0 V [P-P] / 75 Ω, PAL composite, BNC
	Microphone/Line Input	MIC IN and Line IN are selectable. ø3.5 mm monaural mini jack (Applicable microphone: Plug-in power type), Supply voltage: 2.5 V ±0.5 V, Input impedance: approx. 2 kΩ	
	Audio Output	ø3.5 mm stereo mini jack (monaural output) Line level	
	External I/O Terminals	ALARM IN 1 / DAY/NIGHT IN, ALARM IN 2 / ALARM OUT, ALARM IN 3 / AUX OUT (x1 each)	
General	Safety/EMC Standard	UL (UL60950-1), FCC (Part15 ClassA), C-UL (CAN/CSA C22.2 No.60950-1), DOC (ICES003 ClassA)	CE (EN55022 ClassB, EN55024)
	Power Source/ Consumption	12 V DC: approx. 1A PoE: approx. 48 V 250 mA (IEEE802.3af compliant, Class 0 device)	
	Ambient Operating Temperature/Humidity	−10 °C ~ +50 °C (14 °F ~ 122 °F), 90 % or less (without condensation)	
	Dimensions	ø135 x 196 mm (H) (ø5-31/100" x 7-18/25")	
	Mass (approx.)	Camera: 1.2kg (2.65 lbs) Accessories (Camera mount bracket, decorative cover): Approx. 200 g (0.44 lbs)	

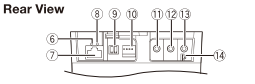
*1 Refer to "Notes on Windows Vista® / Windows® 7 / Windows® 8" on the provided CD-ROM for further information about system requirements for a PC and precautions when using Microsoft® Windows® 8 or Microsoft® Windows® 7 or Microsoft® Windows Vista®.
*2 When using IPv6 for communication, use Microsoft® Windows® 8 or Microsoft® Windows® 7 or Microsoft® Windows Vista®.
*3 Microsoft Windows 7 Starter, Microsoft Windows Vista Starter and Microsoft Windows XP Professional 64-bit Edition are not supported.
*4 H.264 and MPEG-4 are alternative.
*5 [4 : 3] and [16 : 9] are alternative.

Part Names and Functions

Front View

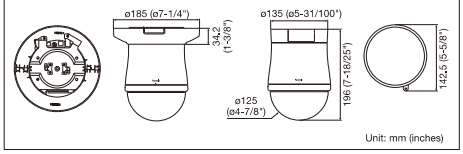


Rear View



① Dome
② SDHC/SD memory Card Slot Cover
③ Live Indicator
④ SDHC/SD Memory Card Slot
⑤ INITIAL SET Button
⑥ Link Indicator(lit when linking)
⑦ Network Connector
⑧ Access Indicator (blinks when accessing)
⑨ 12 V DC Power Supply Terminal
⑩ External I/O Terminals
⑪ Microphone/line Input Connector
⑫ Audio Output Connector
⑬ Monitor Out Connector for Adjustment
⑭ Safety Wire Holder
⑮ Camera Mount Bracket (accessory)
⑯ Safety Wire (fixed with the mount bracket)
⑰ Decorative Cover (accessory)
⑱ Camera
⑲ Dome Cover

Appearance



Unit: mm (inches)

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Important
– Safety Precaution: Carefully read the operating instructions and installation manual before using this product.
– Panasonic cannot be responsible for the performance of the network and/or other manufacturers' products used on the network.

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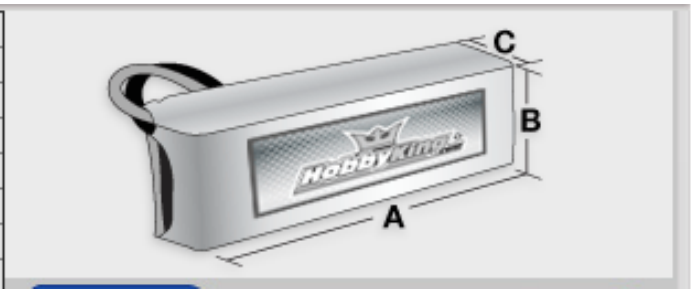
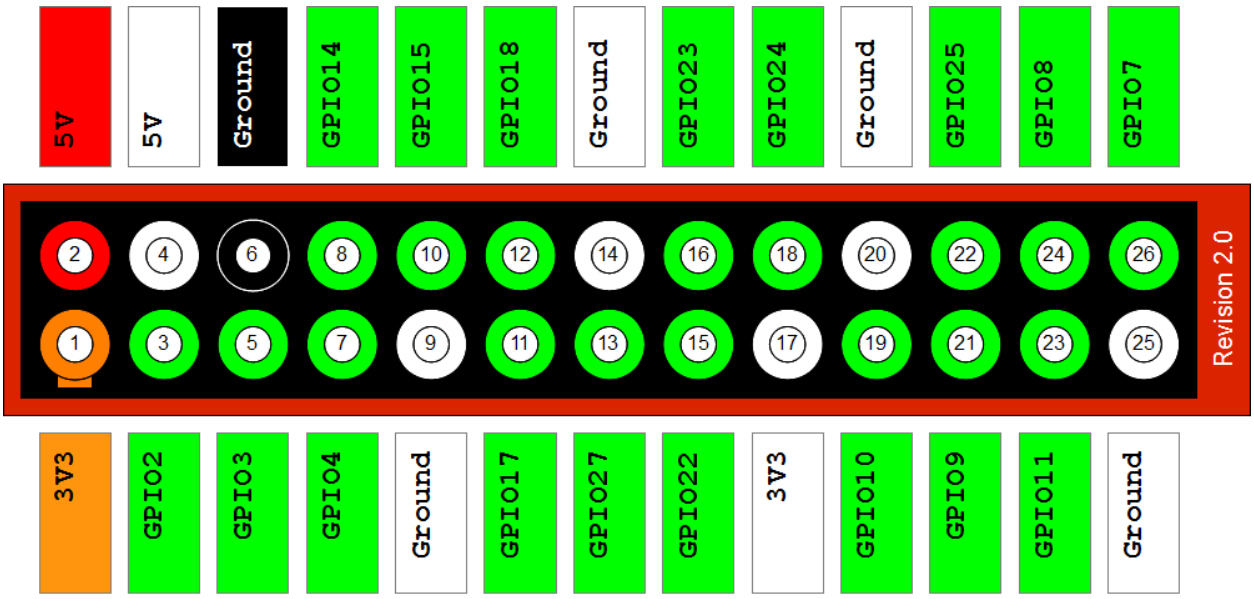
Printed in Japan (2A-077BL)

3. 8000 mAh LiPo Battery

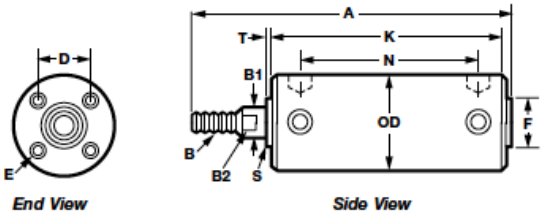
Capacity(mAh)	8000
Config(s)	3
Discharge(c)	30
Weight(g)	644
Max Charge Rate (C)	5
Length-A(mm)	169
Height-B(mm)	69
Width-C(mm)	27



4. Raspberry Pi Pin Diagram



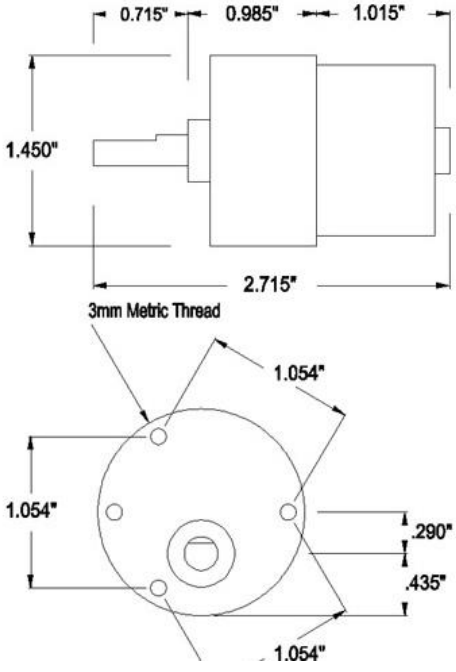
5. Air-Flow Cylinder



Bore Size	Port Size, NPT Female	Retracted Lg. (A)	Rod, Thread Size × Lg. (B)	Rod Dia. (B1)	Wd. Across Flats (B2)	OD	Mounting Holes, Center-to-Center (D)	Mounting Holes, Size × Lg. (E)	(F)	Barrel Lg. (K)	Port, Center-to-Center (N)	Bushing Dia. (S)	Bushing Lg. (T)
¾"	⅛"	3.78"+ Stroke Lg.	¼"-28×0.5"	0.315"	0.24"	1.02"	0.55"	8-32×0.28"	0.472"	2.70"+ Stroke Lg.	1.76"+ Stroke Lg.	0.472"	0.08"
1"	⅛"	3.90"+ Stroke Lg.	5/16"-24×0.5"	0.394"	0.31"	1.22"	0.65"	10-32×0.30"	0.551"	2.70"+ Stroke Lg.	1.76"+ Stroke Lg.	0.551"	0.08"
1¼"	⅛"	4.49"+ Stroke Lg.	7/16"-20×0.75"	0.472"	0.39"	1.50"	0.79"	10-32×0.30"	0.709"	2.78"+ Stroke Lg.	1.88"+ Stroke Lg.	0.709"	0.08"
1½"	⅛"	4.77"+ Stroke Lg.	7/16"-20×0.75"	0.630"	0.55"	1.85"	1.02"	¼"-28×0.47"	0.984"	3.06"+ Stroke Lg.	2.08"+ Stroke Lg.	0.984"	0.08"
2"	¼"	5.68"+ Stroke Lg.	½"-20×0.88"	0.787"	0.71"	2.28"	1.26"	5/16"-24×0.63"	1.181"	3.53"+ Stroke Lg.	2.47"+ Stroke Lg.	1.181"	0.08"
2½"	¼"	5.68"+ Stroke Lg.	½"-20×0.88"	0.787"	0.71"	2.83"	1.50"	⅜"-24×0.63"	1.260"	3.53"+ Stroke Lg.	2.47"+ Stroke Lg.	1.260"	0.08"

6. DC Motor

- Operating Range: 3-12VDC
- Torque @ Max Efficiency: **127 oz-in.@12VDC**
- Torque @ Stall: 368 oz-in.@12VDC
- Gear train damage can occur if stalled (locked)
- .240" (6mm) Diameter Shaft
- No load current: 45mA
- No load current @ Max Efficiency: 95mA (12V)
- No load speed: **10 RPM**
- No load speed @ Max Efficiency: 7.96 RPM
- Gear ratio: 300:1
- Motor size: 1.30"Dia. x 1.015"L
- Gear size: 1.45"Dia. x .985"L
- Shaft size: 0.24" (6mm) Dia. x 0.715"L
- Weight: 0.2813 lbs. (4.5 oz.)
- DC reversible motors
- Solder type terminal
- High torque construction
- Oil bearing design for long service life
- Insulation resistance: 10 MOhm
- Dielectric Strength: 300VDC



Enclosure Layout

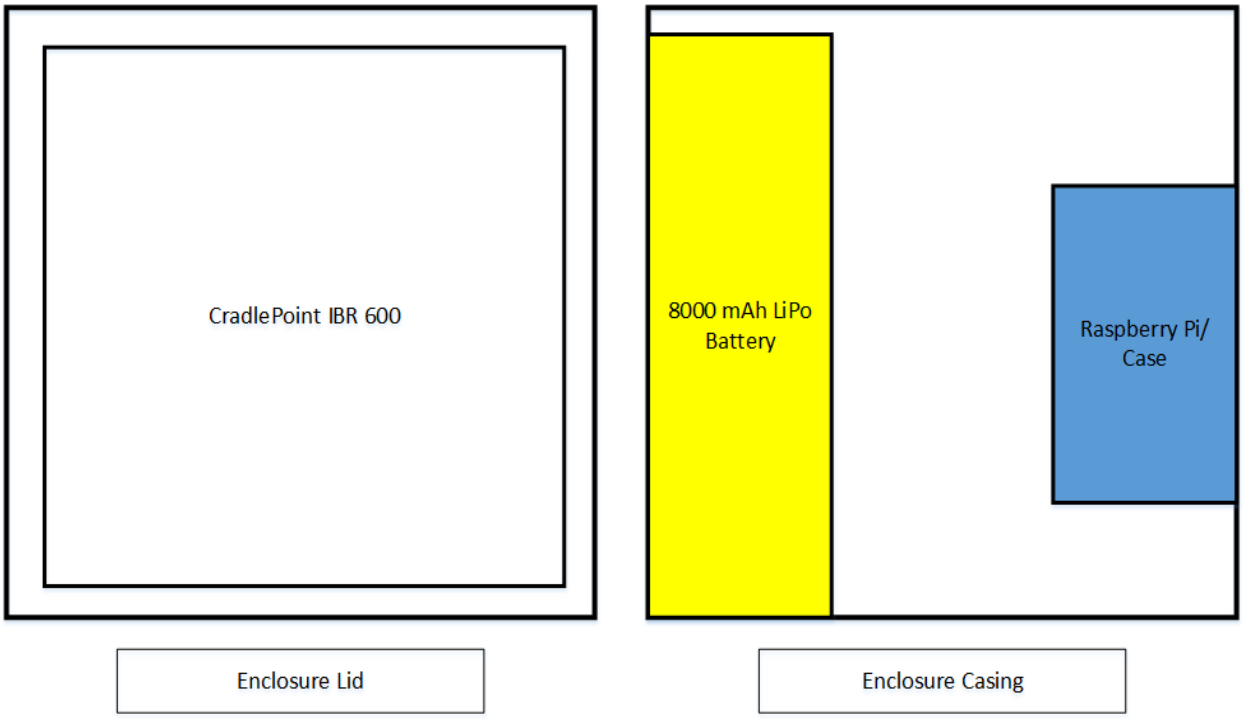
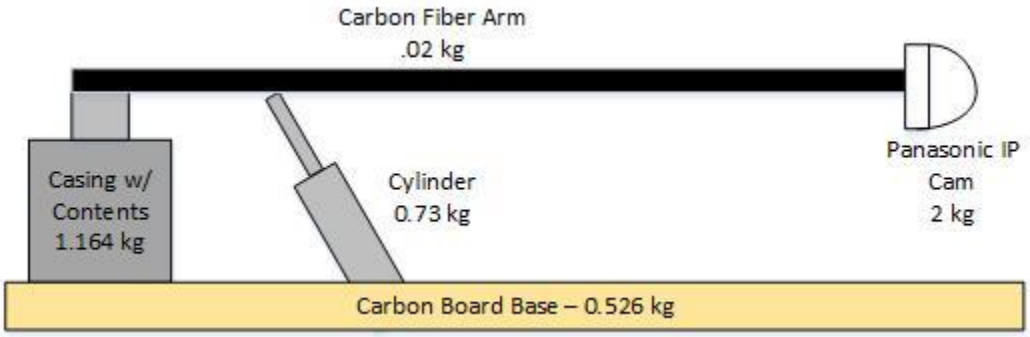


Figure 5: Layout of Aluminum Enclosure on Base Station

Calculations

- **Center of Gravity**



$$CG\ (Without\ Rover's\ Help) = \frac{(0.526\ kg)(.04\ ft) + (0.73)(0.1667) + (1.164)(0.0833) + (0.02)(0.25) + (2)(0.25)}{0.526 + 0.73 + 1.164 + 0.02 + 2}$$

= 0.1677 ft ≈ 2 inches high

$$CG\ (With\ Rover's\ Help) = \frac{(0.526\ kg)(.04\ ft) + (0.73)(0.1667) + (1.164)(0.0833) + (0.02)(0.25) + (2)(0.25) + (40)(0)}{0.526 + 0.73 + 1.164 + 0.02 + 2 + 40}$$

= 0.0168 ft

- **Pressure of Cylinder**

$$Pressure\ (lbs) = Pressure\ (Newtons) \times 0.2248$$

P = 450(0.2248)

P = 101.272 lbs

- **Torque of Cylinder**

$$Torque\ (lb - ft) = F(lb) \times D(ft)$$

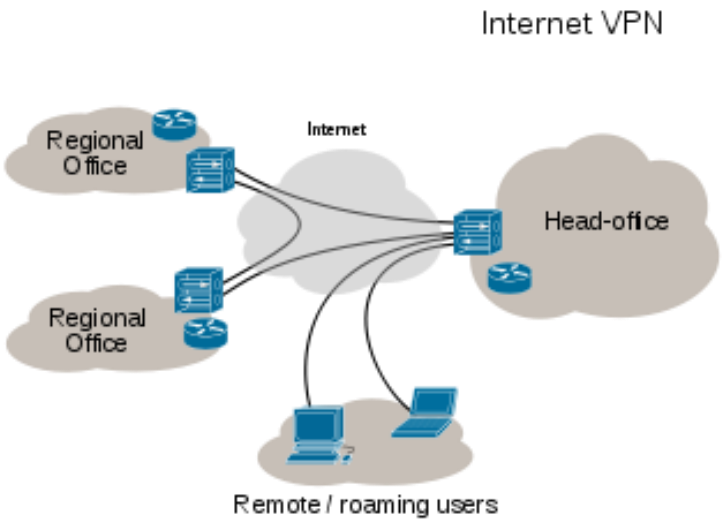
*D was calculated based on starting to finishing location of cylinder mount on mast

$$T = 101.272(lbs) * (0.3535\ ft) = 35.805\ lb - ft$$

4.0 Software

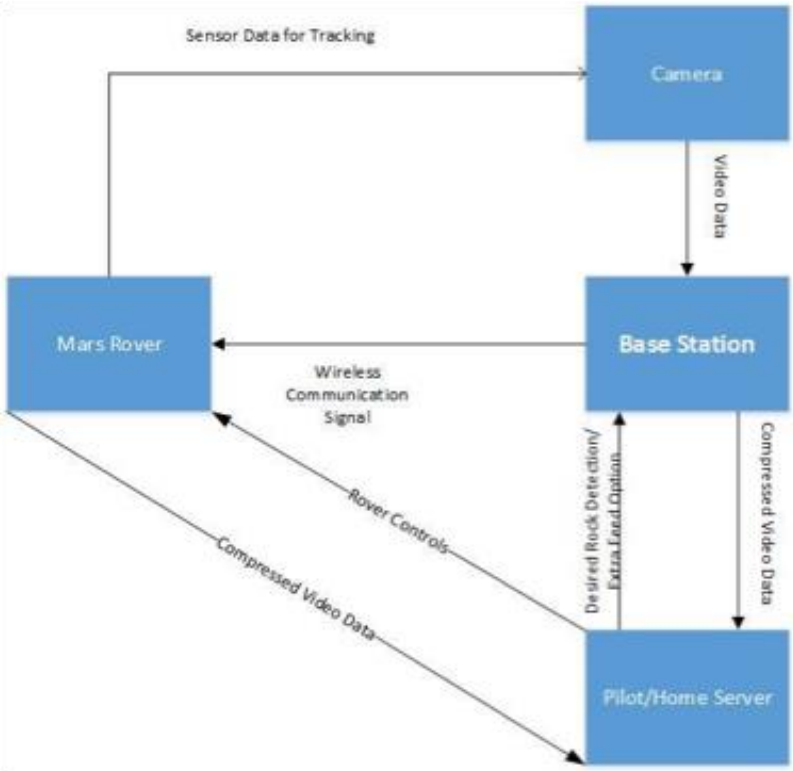
The premise of the senior design team's project entailed a complex communication network, as well as video compression . The team was tasked with this because in last year's competition the Mars rover the WVU Robotics fell short of expectations and goals because of communications failure. There were dead spots on last year's competition field, to resolve the problem this year's design team began with the idea of a base station to route all communications through as well as extend the range of the network to encompass all areas on the field even in the pits areas where the team struggled last year. The modular design consists of the base station, the Mars rover, and a server here at West Virginia University where the operator will remotely control the rover.

The first and foremost goal of the software was to implement the VPN network with which the communications will take place. The base station contains a Cradle Point IBR 600 router; this router has the capability of extending a cellular data network over wifi. The initial design had taken a Verizon network into account, which uses CDMA protocols. After the design started to become a reality it became more practical to use the AT&T network, which uses GSM protocols. A secure virtual private network will be used to connect the rover, base station, and the server here at WVU. The network has to be secure to ensure that no one else can access our devices while in operation. Luckily the router that was chosen and purchased fir the base station comes pre packaged with an interface for simple implementation of a VPN. The network is going to be under a large strain as compressed video feeds are passed from the camera mounted atop the base station as well as the camera on the Mars rover. While all that data needs to be transferred at high rates and allowing for as little latency as possible. The network will also have the load of rover commands passing over it.

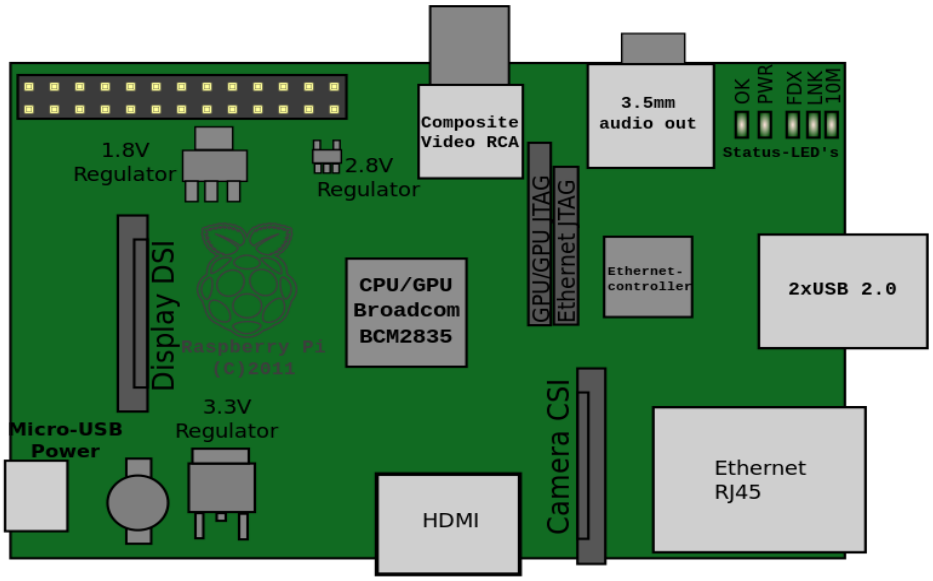


Visualization of a Virtual Private Network

Below is a diagram showing the interconnections of the network.

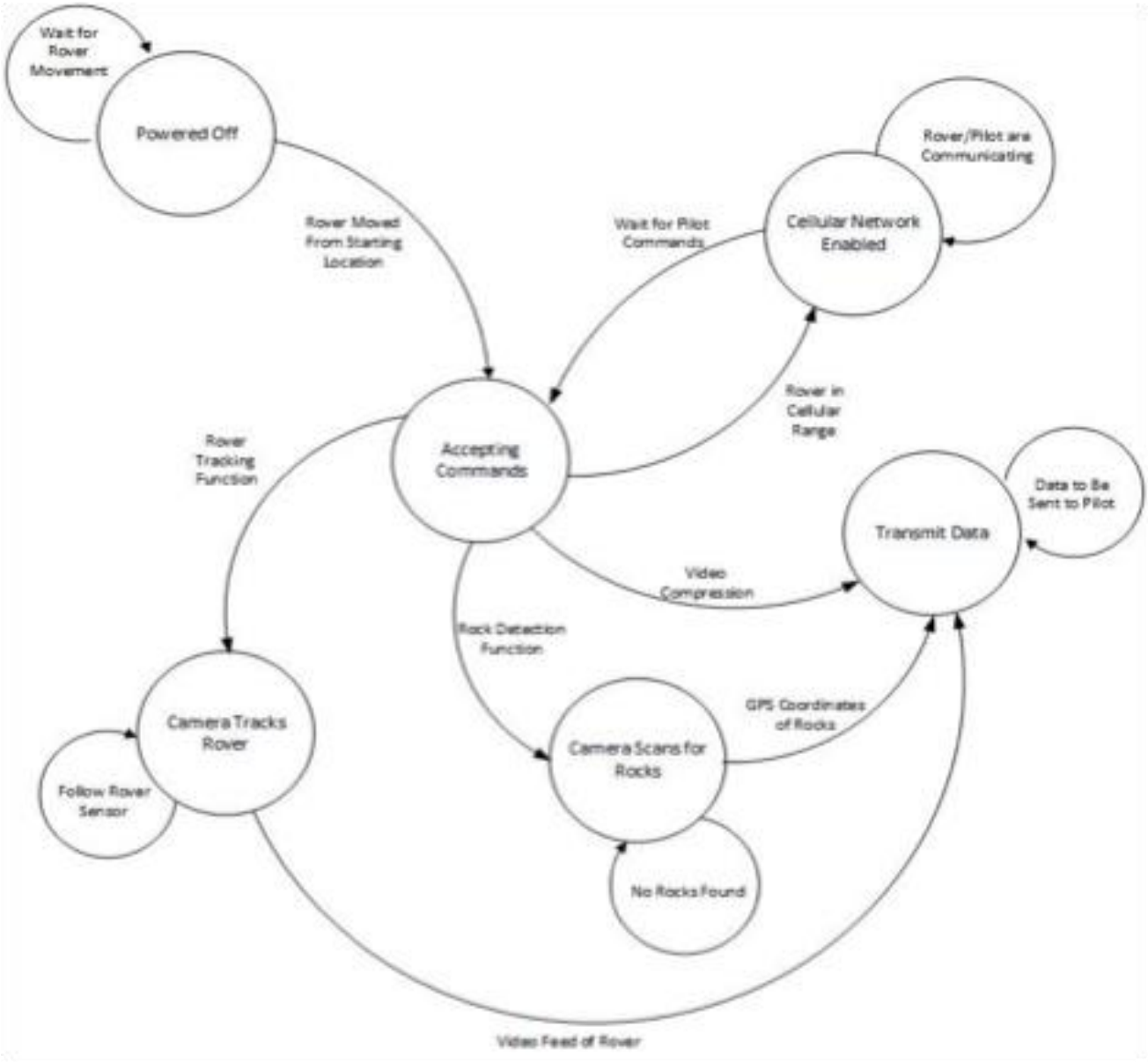


The micro-controller that was chosen was the Raspberry Pi which will take in the video data stream and then will process the incoming data and then send out compressed video data. The Raspberry Pi micro-controller is a credit card sized computer. There are numerous uses for this mighty controller but the specific use for this project is video compression software and VPN management. The Raspberry Pi uses a Linux kernel operating system. Fortunately the Raspberry Pi is very power efficient and will not draw way from the demands of router or camera on the base station. Below is the layout of the Raspberry Pi circuit board.



The Raspberry Pi is used to initialize the VPN and control the DC motor, solenoid, and read data from the switches. This is done with a combination of programs written in C# and Python. C# was chosen to be able to integrate the legacy communications system written for the Mars Rover in the past, while Python was chosen for the ease of use in reading the GPIO data with the Pi.

The rover operator in Morgantown will have in front of him a user interface that will show all the commands available. The pilot also has the option to manipulate any file or command on the fly as he sees fit. The interface is streamlined and simple providing very intuitive commands. The communication between the pilot, base station, and rover has a clear defined flow structure. The information flow and be described in the graph below.



5.0 Source Code Listing

DC Motor

```
import RPi.GPIO as io
io.setmode(io.BCM)


in1_pin = 4
in2_pin = 17
io.setup(in1_pin, io.OUT)
io.setup(in2_pin, io.OUT)
def set(property, value):
    try:
        f = open("/sys/class/rpi-pwm/pwm0/" + property, 'w')
        f.write(value)
        f.close()
    except:
        print("Error writing to: " + property + " value: " + value)
set("delayed", "0")
set("mode", "pwm")
set("frequency", "500")
set("active", "1")
def clockwise():
    io.output(in1_pin, True)
    io.output(in2_pin, False)
def counter_clockwise():
    io.output(in1_pin, False)
    io.output(in2_pin, True)
clockwise()
while True:
    cmd = raw_input("Command, f/r 0..9, E.g. f5 :")
```

```
    direction = cmd[0]
    if direction == "f":
        clockwise()
    else:
        counter_clockwise()
    speed = int(cmd[1]) * 11
    set("duty", str(speed))
```

Servo

```
# Servo Control
import time
def set(property, value):
 try:
 f = open("/sys/class/rpi-pwm/pwm0/" + property, 'w')
 f.write(value)
 f.close()
 except:
 print("Error writing to: " + property + " value: " + value)
def setServo(angle):
 set("servo", str(angle))
set("delayed", "0")
set("mode", "servo")
set("servo_max", "180")
set("active", "1")
delay_period = 0.01
while True:
 for angle in range(0, 180):
 setServo(angle)
 time.sleep(delay_period)
```

```
for angle in range(0, 180):
setServo(180 - angle)
time.sleep(delay_period)
```

6.0 Test Results

Our base station design has a few key features that without them working correctly the base station would serve no purpose to the Mars Rover team. The bandwidth of the network, camera optical zoom, deployment of the base station, and total power consumption are a few of the key components that had to be tested.

The main component of our base station is the communications network. To test the network we had to make sure that we had enough bandwidth on the routers. We were able to test the bandwidth and we had the appropriate amount to communicate through the cellular network. We also needed the camera to be able to communicate with the router, so that the compressed video feed could be sent back to pilot or the system operator. Our first tests to send the video feed directly from the camera to the router failed. This method was unable to work and we had to find another way to be able to send the compressed video feed. The router wouldn't connect to the camera because it needed a static IP address, but the cost of a static IP wasn't feasible. To get around this we decided to use a Raspberry Pie Microcontroller. The video feed would be sent from the camera to the Raspberry Pie then relayed to the router. The tests were successful for this configuration.

Not only did we have to test the capability to connect the camera to the network, but we also had to test the cameras zoom ability and test the camera mount we made for stability. The IP camera is supposed to be capable of up to 80x zoom with the proper configurations. Under our tests we were able to get the camera to a max of 72x zoom which is perfectly fine for our project. After numerous tests when mounting the camera on the top of the base station, we realized that the camera had to be mounted as if it were mounted on a ceiling. The way that we original planned to mount the camera would not work because all of the video feed would be of the sky and upside-down. To fix this problem we had to make a mount so that the camera would be in the same position as if it were mounted on the ceiling. We were able to make the mount and we tested to make sure that is was sturdy enough to support the camera.

Another key aspect of our project is the ability to raise the arm up and extend it out to reach a height that the entire competition area is visible to the camera at the top of the arm. When testing the strong arm to raise the weight, the tests were successful and the strong arm was able to list the desired amount of weight. However when we incorporated the self-extending pulley system, the strong arm could not lift and extend the arm. We found out that we needed a stronger strong arm or we had to cut weight.

The final thing that we tested was the base stations power consumption. There are three electronics onboard the base station that needs a power source to function. The onboard electronics are the Cradle Point router, the Panasonic IP camera, and the Raspberry Pie. The Cradle Point router has a power consumption of 1500mAh, the IP camera has a power

consumption of 1000mAh, and the Raspberry Pie has a power consumption of 700mAh. The combined power consumption is 3200mAh, so our 8000mAh LiPo battery should work just fine for the hour of the competition.

7.0 Safety Precautions

- Wear safety glasses
    - Necessary to protect the eyes from sparks, or fragments of metal and such.
- Keep work area clean
    - A messy work area adds additional unnecessary hazards. Examples could be materials left on the floor could cause tripping or sharp tools unknowing located could cause injury.
- Always have partner present to assist
    - Whether it be for an emergency or any other type of assistance
- Make sure everyone is aware when operating dangerous machinery
    - When beginning to operate any machinery make sure everyone present is aware so that they are prepared to avoid the area and take caution.
- Wear ear protection
    - If exposed to loud machinery for an extended period of time noise protection is necessary.
- Keep hands free from dangerous areas
    - Make sure hands are clear of all cutting areas
- Make sure all components are securely mounted before operation
    - Be sure that all components of the base station are secured prior to deployment
    - Make sure all machining equipment is secure in order to prevent injury.
- Avoid baggy or dangly garments when operating machinery
    - In order to prevent entrapment.
- Do not operate machinery unless you have an understanding of how it operates
    - Operating without proper knowledge could result in injury.

8.0 Reflections

The main reason of the delay on building the actual base station was constant design changes. Due to the weight restriction and the ways to raise the camera, the design was changed numerous times. This led to the delay of ordering parts and necessary materials. If the group could find the best design and stick with it, gathering the parts and materials could start earlier and the construction of the base station could start earlier, as well.

The early design relied on 3D printing heavily and cutting parts using a CNC machine. After printed parts, it was found out that the printed parts are not strong and flexible enough to be used in the base station. It was not expected during the design. This also led to the delay of ordering parts and materials. Also, the CNC that the group expected to utilize, became unavailable to use for the Base Station during the smester.

With the delays mentioned above, the group ordered the parts whenever it was decided to be used. Therefore, the base station could only be built until certain point and waited for the other parts to arrive. These delays should be avoided if possible.

Appendix 1 – User Manual

The Base Station has been designed to be placed underneath the Mars Rover. To begin the extension of the tower, the Mars Rover is driven off of the base station, which allows the pneumatic cylinder to complete the first stage of extension. After the first stage, the rover will continue to drive forward. When the mast hits a “stopper,” which keeps a vertical position, the motor will begin the use a pulley to extend the top section of the mast and camera.

The base station will be powered once the battery is connected to the electrical system contained within the base of the station. This will be done prior to the start of the competition. Connection of the battery will commence the boot up of the camera, router, and raspberry pi. The router’s IP address will then need to be acquired by connecting into it by the raspberry pi that can relay the needed information about the dynamic IP of the router.

Essentially, all that is required of the user is to place the compressed Base Station underneath the rover, and to plug in the battery. It is best to charge the battery prior to each hour-long run during the competition.

Appendix 2 – Maintenance Manual

Maintenance of the base station during the competition, during testing, and at regular intervals will include the following:

- Checking the pressure of the pneumatic cylinder. It should remain at 75 psi before beginning each competition run.
- Nuts and bolts remain tight
- Electronic enclosure remains sealed
- Check for fraying in pulley wires
- Greasing/Lubing pulley wheels
- IP Camera lenses remains grime free
- Inspection of the base of the station for cracks or warping
- Charging the battery prior to each competition run.
- Replacing the Teflon tape or o-rings for the cylinder every 100 compressions.

Appendix 3 – Original Design Proposal

Mars Rover Base Station Design Proposal

Faculty Instructor: Dr. Reddy Faculty Advisor: Dr. Powsiri Klinkhachorn

Group Eight: Wei-Ting Chang, Nathan Haney, Zakary Hooper, James Hunsucker, Rylan Maynard, Christopher Peyatt

November 4, 2013

1.0 Introduction

Mars is now the planet that interests space-related organizations like NASA the most. Due to the distance, dangers, and the unknowns on Mars, exploring the planet is not a task that astronauts can or will take. Robots have taken over this job for the foreseeable future. The Several Mars Rovers have been designed and traveled to Mars to gather as much information as possible. Since the investment and labor is so intensive to send one of these machines the great distance to Mars, the design must be flawless and not incur any malfunctions throughout any difficult situation that it may encounter in its lifetime. A well-functioning rover should be able to travel on Mars, analyze the surroundings and transmit data back to the Earth.

RASC-AL Exploration Robo-Ops Competition is a NASA sponsored competition that is held in Houston, Texas every year. Eight universities are to be chosen from all applicants to participate in the competition. Each school is required to design and build their own version of the Mars Rover. Certain restrictions are applied to the design of the Mars Rover. Its dimensions cannot exceed 1m x 1m x 0.5m and the whole device must weigh less than 45 kilograms. All add-ons to the robot are included in the dimension and weight restriction. The rover should be able to traverse over obstacles up to 10 cm in height, negotiate upslopes and downslopes up to a 33% grade and travel through sand, gravel, rocks, and craters. The course is built to simulate the possible terrains on Mars. The main way for scoring points in the competition is by locating “space rocks,” oddly shaped rocks that have been brightly painted, and collecting them in an on-board bin.

In order to simulate the circumstance of the rover being controlled remotely from earth, the pilot of each rover in the competition will be controlling the rover from his or her home university. Without communicating with teammates in Houston, the pilot needs to locate the colored rocks, travel to them, and collect and place the rocks in the bin. There are six different colors, with each color having a different assigned point value. The winner will be determined by how many colored rocks, and the total point value of the rocks, that the rover brings back. The team with the highest point total will take home first place in the performance section of the competition. Violating any rules of the competition will result in a point penalty and a disadvantageous spot in the starting order.

The goal of NASA by sponsoring the RASC-AL Exploration Robo-Ops competition is “to engage as many people as possible in space exploration missions.” Therefore, each team is required to partner with public organizations while they are working on the rover. This outreach makes up a portion of the competition, and the teams with the most outreach hours will achieve a high score in this section.

The West Virginia University robotics team is one of the eight teams that have been chosen to participate in the competition, the third straight year for the team. Although the team is relatively new to the competition, designs in previous years have proven the WVU students are more than capable of producing a competition-worthy robot. In 2012, the team's first trip to Houston, the team finished in fourth place overall. With the improvements made after the 2012 competition, the team still did not manage to win first place the following year. The major problems in the 2013 competition were with the communications. The video feeds sent to the pilot from the rover's on-board cameras were grainy and had a delay that ranged from three to fifteen seconds. This increased the difficulty for pilot to control the robot on the field, or as the NASA officials refer to it, the "Rock Yard." This design included the communications being handled by a Verizon 3G/4G wireless card. The rover couldn't communicate with the pilot effectively because the cellular signal that reached the rover was not strong enough to handle data compression and transmission.

Therefore, the main goal for this year's competition will be to improve the communication systems. Since the rover will start at the highest point of the course in the competition, a base station will be placed at the starting location. The base station will be used as a relay station between the pilot and the rover. It will receive the commands from the pilot through cellular network and communicate with the rover over a 3G/4G integrated router. On top of the base station, a camera will be installed to help guide the pilot, locate the rover, and search for the colored rocks. A user interface is to be developed that will allow the pilot to choose the function of the camera and display the appropriate data. It will be designed to let the pilot see different camera feeds and switch between camera feeds easily.

The following sections will show more details of the problem, how the robotics team will achieve these goals, the actual design of the base station, test plans and project management plan.

2.0 Extended Problem Statement

2.1 Executive Summary

The primary objective of this team's project, the Mars Rover Redesign, is to design, create, and test a working robot to compete in the 2014 RASC-AL Exploration Robo-Ops Competition. The robotics program at West Virginia University has competed in this competition in the previous two years, but has peaked with a fourth place finish. The team hopes to improve on this finishing position and win the competition with our design.

Aspects from previous robots will be used in our initial design. Lessons learned in each

unsuccessful attempt at winning the competition will contribute to the knowledge base in which the team will meet design challenges. Our faculty sponsor, Dr. Klinkhachorn, has vast experience in building and designing to meet specific robotic functions and requirements. The team also is being aided by members of the robotic team, many of which have competed in this competition in previous years.

The main focus of the team's project will be to design a communications base station that will be placed at the starting point of the competition. This base station will use a camera, antennas, and a cellular communications router. These components will be used to locate the coordinates of scoring opportunities and allow the communications of other data to the robot. This will enable the pilots of the robot to have an easier time viewing and driving from remote locations, and it will equip them with more knowledge about the competition field and other surroundings.

By simply being accepted into the competition, the team will be generating $10,000 that will enable the robotics program to compete in competitions this year, as well as the future. Further money generated will depend on the work of our team, including placing in the competition, volunteer outreach, and working with corporate sponsors.

Components of our design have the potential to contribute in technological areas outside of robotics. This includes the communications overhaul that must be done to the robot. The competition requirements mandate that the robot, which will be in Houston, Texas, be controlled and driven from the WVU campus. The improvements made in remote control can be applied in any semi-autonomous application, including the self-navigating vehicles that are currently being prototyped.

2.2 Needs

The needs for this project have been set by experiences from years past in this competition. Those who judged the competition last year told the team that they loved the physical design of the robot and did not want it to be changed in any major way. However, this year the team will be supplementing the robot with a stationary base station that will be deployed with the robot during the competition. The base station will enhance communication systems on the robot and provide the team more information to make decisions with during the competition. The needs of this base station, as set by Dr. Klink, include a reinforcement of the entire communications network for the rover, a web-based graphical user interface (GUI), and support for the actual construction of the Mars Rover.

The major issue that faulted the team's previous attempt was communications. Previously the team had used a Verizon 4G cellular network in order to provide internet to the rover. This is

needed in order to have access to the robot's multiple video feeds and to get controls to the rover from Morgantown to Houston. The problem that was presented last year

was a loss of communications between the rover and Morgantown. This was due to there being "dead zones" and "lunar pits," in these areas we would lose contact with the rover and it would be left useless. The solution that is our main project is to create a base station. This base station is to prevent any loss of communications so that the team does not come upon the same issues as last year.

A web-based application will be developed for the benefit of the rover pilot that will be manning controls in Morgantown. In the past, commercial software was used that did not fully meet the needs and requirements for the team to effectively communicate and perform to its full capabilities. This application should include multiple viewing screens for separate cameras, a sonar-like GPS tracking system to keep track of the robot in the field, and the coordinates for scoring opportunities. A rock detection program will be written for the base station that will determine the areas within the field with the highest concentration of rocks, which must be collected in order to score points for the competition. The location of these clusters will also be displayed on the GPS sonar of the GUI.

Along with these other needs our group is providing support for all other aspects of the Mars Rover. This support consists of designing, any re-building that needs to occur, and on the spot troubleshooting as the team moves forward. In previous years the team has had to rush to complete the rover in time for the competition. This gave them little to no time for testing before going to Houston. Our group hopes to prevent this need to rush by being there for every step to complete everything in a timely nature. This will allow the team to know that the rover is the best that it can be for this year's competition. Also in being there for support of the rest of the team we can assure that the base station is completely and properly integrated into any new work that is occurring on the Mars Rover.

2.3 Objectives

Each of our objectives that have been determined are based off of the initial needs stated. Clearly with the team wishing to compete in the RASC0AL Robo-Ops Competition the main objective is to win the competition. Any improvement in placement would demonstrate the efforts that WVU has put into this competition are worth the time and dedication of the students working towards this project. Each year so far there have been specific flaws that have prevent WVU from being in the top ranks of the competition. A high placement in this year's competition would bring a much greater respect to WVU's robotics program.

As for the design itself, the base station can be broken down into three overarching objectives

that can be separated. Our first is physical design of the base station, including the collapsible arm that will support the camera and cellular antennas. The aspects of the arm that will serve as the objectives include configuring the motors of the arm, designing the arm so that it can both collapse and extend at least two meters above the ground, and providing a platform the will support and rotate the camera. All of these sub-objectives will contribute to a successful arm, which is essential to the success and usefulness of the base station. For the body, or base, of the base station, several objectives must be met for this project to succeed. To begin with, the team must get creative to map out the electrical system and all motors so that it will fit in the confined space that has been allotted for the fully collapsed base station. The base must also provide some sort of ventilation so that the minimum peak temperature among the electronics is not reached. Lastly, the cellular network router must be able to receive and transmit at an optimal signal to ensure the highest quality communications.

Most of the communications will be done through Cradlepoint industrial routers. These high-tech routers are one of the few in the field that support cellular connectivity, which is a key design component for the team. Our objective, as it pertains to these routers, is to configure them to meet our needs. A VPN will be configured to ensure high speed data transmission between the base station, the rover, and the LCSEE servers on the WVU campus. To enable the VPN on the routers, all ports will be reconfigured to accept incoming and outgoing connections. Also, the team will design two sectorized antennas that will be placed on

the base station and the robot. Using the GPS tracking system, the antennas will move correspondingly to provide the highest signal strength at all points of the competition field. This should prevent service being lost due to the “lunar pits,” as in previous years.

The third major objective is to complete the GUI based program to integrate all of the incoming information that is being collected at the site in Houston. By keeping the controls and interface simple, the pilots will be able to focus their full attention on completing the objectives of the competition. The initial design calls for four separate camera viewing windows so that all angles of the robot, and the field of view is always observable. In order to handle all of the bandwidth required to transmit simultaneous video feeds, all of the data must be compressed from the camera before it is transmitted over the network. The packets of data will then be decompressed at WVU on the home servers. The GPS data will display the location of the rover, in reference to the rest of the Rock Yard, on a sonar style display. The GPS coordinates of the detected rock clusters will be displayed on the sonar giving the pilots multiple options for the best possible path.

2.4 Background

According to their website, the Revolutionary Aerospace Systems Concepts – Academic Linkages (RASC-AL) System Level Robotics Systems Competition (Robo-Ops) "focuses on a specific system in an interplanetary mission – robotics." The competition invites teams made up of undergraduate and graduate students to form a multidisciplinary team and build a "planetary rover prototype and demonstrate its capabilities to perform a series of tasks in field tests." These field tests take place at the NASA Johnson Space Center's Rock Yard, where teams must scour for brightly painted rocks that serve as scoring markers if the robot can collect the rocks and place them in an on-board bin.

From the competition's rules, teams must operate the rovers remotely from the "mission control center" of their home universities. A small crew of team members are allowed to bring the rover to the Rock Yard and perform maintenance and modifications while on-site.

The goal of the competition is to replicates the cooperation that must be present between robots and astronauts on future space exploration missions. The robot is not the only deliverable that teams must present to the competition judges. Each team is required to submit a technical paper, poster, and demonstrate an interactive Education and Public Outreach component that shows "participatory exploration approaches" for future NASA missions.

This will be the third year that West Virginia University has applied to compete in the RASC-AL Robo-Ops Competition. Each of the last two years, the robotic team has finished in fourth place. A first place finishing position has been obtainable in both years, but mechanical and communication failures have hindered the success of the team in Houston. Dr. Klink is adamant that the team improves this trend, or WVU will not be present in future competitions.

In June 2012, the team had the heaviest robot of all of the teams, which according to the competition rules, meant that they had to go first. Without being able to see other teams navigate the course through a video stream (another competition rule), the rover became caught up in a "crater" in the Rock Yard. This situation had not been tested, so the pilots put the robot at maximum speed in an attempt to dislodge the robot. In doing so, the servos for the rear wheels became maxed out and began to malfunction. The robot was no longer operational, but enough rocks had been collected that the team secured fourth place.

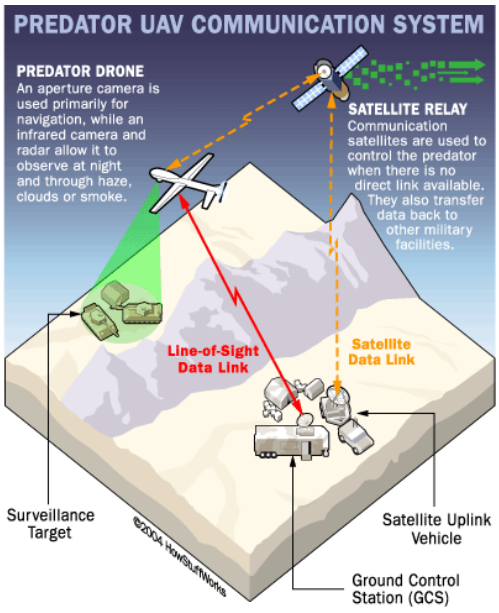
This past June, the team made mechanical testing a priority to avoid a situation like the previous year. While the team still measured in with the heaviest robot and had to make its run first, a new "rocker-bogie" chassis allowed the robot to move in and out of craters and avoid getting stuck. This chassis design is based on the design of Curiosity, the actual NASA rover that has been traversing Mars since August 5, 2012. Even with the improved design and increased

testing, issues were soon to arise. The on-board cameras (four total) were supposed to show a video feed at “home base,” the robotics laboratory in the Engineering Research Building on the Evansdale Campus. The communications between the on-board computer and the station that had been set up here in Morgantown, that there was a twenty second lag in the video feed or sometimes the feed would go out completely. This made piloting the robot virtually impossible and, despite the improved mechanical design, WVU still only brought home fourth place.

This year, the team hopes to combine the improved chassis design with improved communications. The base station that the senior design team will provide will give the robot more support while in the Rock Yard and allow for easier transmission of the video feed to Morgantown. A 3G/4G router will utilize a cellular data plan to compress the data and transmit it to our laboratory. This added support will increase the bandwidth and speed of all of the data being sent and received between the robot, the base station, and our home computer.

The team is basing this idea on the communications taking place in current military applications. The Predator Unmanned Aerial Vehicle (UAV) is one of many new and proud innovations that the military is using for aid during warfare, recon, and scouting. The Predator can run autonomously or be controlled remotely, much like the rover that we will be building. The figure below gives a detailed breakdown of the communication system that links a pilot to the Predator. Since the team does not have the ability, or the funds, to purchase satellite space and exactly mimic the Predator, it has been decided that transferring the data through a cellular network would be the best solution.

Figure 1: Layout of Predator UAV Communication System


PREDATOR UAV COMMUNICATION SYSTEM
PREDATOR DRONE
An aperture camera is used primarily for navigation, while an infrared camera and radar allow it to observe at night and through haze, clouds or smoke.
SATELLITE RELAY
Communication satellites are used to control the predator when there is no direct link available. They also transfer data back to other military facilities.
Line-of-Sight Data Link
Satellite Data Link
Surveillance Target
Satellite Uplink Vehicle
Ground Control Station (GCS)
©2004 HowStuffWorks

By deciding to use a cellular network to link the communication points, or nodes, the base station has the potential to be accepted and utilized by the general public. Any cellular telephone customer that has a data plan could purchase a similar base station for various uses. All robotic or Radio Control (RC) hobbyist could have the added dimension of long distance remote control. With further development, which would not be included in the scope of this project, a mobile app or web interface could be developed for ease of use and marketability. Taking this idea a step further, remote control has unlimited potential to be useful in the automobile, railroad, and airline industries.

2.5 Stakeholder Goals

The WVU Robotics team has been working to perfect this robot for the past two years. With the addition of the base station the team has hopes to advance in the competition. If the base station does not work properly, the work that has been done year round will be jeopardized and the communications system will have to be redesigned in an unrealistic time frame.

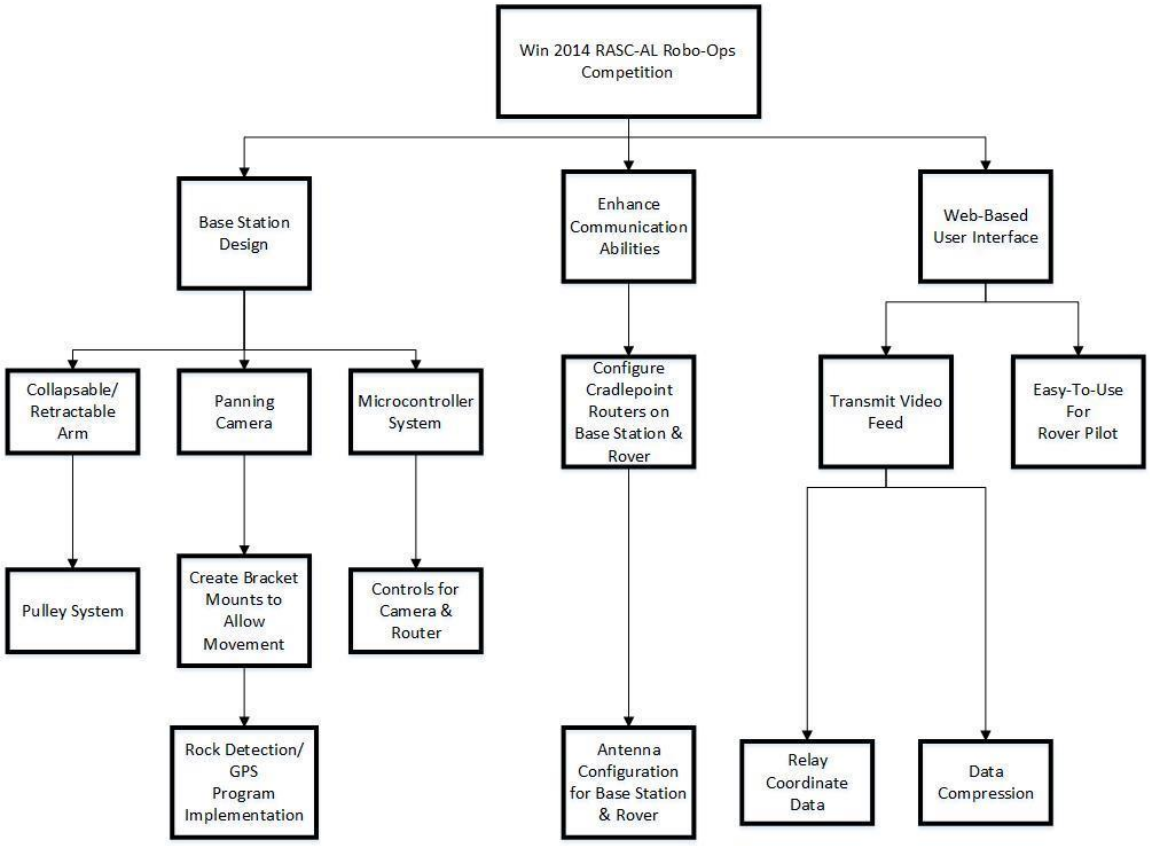
The second stakeholder in our project is Dr. Klink. He is not only the faculty advisor for this project, but Dr. Klink is also responsible for advising and maintaining the robotics club. He is in charge of all finances for our project and the robotics club while also determining which competitions and projects WVU should be entered in. Dr. Klink has expressed his concern for future RASC-AL competitions, and has informed the team that another fourth place finish may mean that WVU will no longer invest in the rover robots.

Another stakeholder in this project is the NASA West Virginia University Space Grant Consortium. This group has invested a large amount of funds and countless hours into helping the robotics team with fundraising, outreach, and NASA obligations. It would be ideal for the base station to aid the robotics team and return the Space Grant Consortium investments with a win in the competition.

The last, and probably the most obvious, stakeholder in the success of the group's design is the Lane Department of Computer Science (LCSEE) and West Virginia University as a whole. If the team is able to finish the competition in first place, it not only will reaffirm the reputation of the department and the robotics program, but it will also give good publicity and outreach on the school's behalf. Prospective students interested in Electrical, Computer, or Mechanical Engineering, or even if it is just an interest in robotics, will know that WVU and the LCSEE provide an opportunity to learn and participate in programs that rival any engineering program in the country.

All stakeholders in this project have the same goal: to win the 2014 RASC-AL Robo-Ops Competition. By winning the competition, the senior design team will generate revenue for the organization, provide reasons for the robotics team to continue to participate in this competition, and reinforce the reputation that WVU robotics has developed over the course of just a few years.

2.6 Objective Tree



2.7 Ranking of Requirements

All of the needs listed above could be viewed as the biggest and most important aspect of the project. If the communications do not hold up, the team is at risk to lose the competition. Without a user interface for the pilot, how could he or she maneuver the rover? If a finished robot is not complete in a short amount of time, the team will not be able to test the base station to ensure functionality, robustness, and convenience.

The number one priority for this project is to ensure that the communications network is vastly improved from previous competitions. A video can be viewed at the following website to show a glimpse of the troubles that were faced during the 2013 competition in regards to communications: http://www.ustream.tv/channel/wvu-mars-rover. As shown, it seems impossible to get a continual video feed of good quality. According to the pilots of the rover, the communications were solely responsible for WVU not winning last year's competition. By improving the quality of signal, the bandwidth and data rate can be improved for the link

between the home base and the rover in Houston. This will allow for a better video signal that the pilots will use to drive the team to victory.

Obviously, an improved communications network will not mean anything if the pilots are unable to see where they are going or if they cannot find scoring opportunities in the field. This is where the GUI application will assist the team in reaching the goals that have been set. By providing multiple camera views, a GPS tracking system for the robot, and a rock detection system, the GUI will provide more information to the pilots and allow them to make better decisions and achieve a higher score for the team. The reason for this need being second, rather than first, is that the GUI will have no use if the communications are not established, and a backup is available in the form of the commercial software that has been used in the past.

Supporting the robotics team in building the robot not only shows the team's commitment to the success of the rover in the competition, but it also will give the team a better understanding of the internal components of the robot that will be useful when configuring the communications on-board the rover. The team will need deep knowledge of the cameras and the computers used on the robot for the purposes of the GUI. There is only so much that can be learned by reading specifications and data sheets from the manufacturers. Providing the robotics team with a larger workforce to build the rover will result in a brisk pace and faster finishing dates. The sooner that the team has the robot fully functional, then the sooner the team can test both the robot and the base station.

2.8 Conclusion

The previous year's robot is of excellent design. If not for the breakdown in communications last year WVU's would have been one of the top performers in the competition. In order to achieve this higher placement in the competition the team's objective is to create this base station to ensure a strong, uninterrupted line of communication between

the robot in Houston and the pilot in Morgantown. In addition to building this component in order to make the pilot's task easier the GUI is also a valuable addition to the robot. By providing assistance for the WVU Robotics team it can be assured that everything is built and tested before taking the robot to Houston for the competition.

3.0 Requirements Specification

3.1 Function Requirements

2.1.1. Raise_Arm() This function will raise the arm of the Mars Rover while it is in motion.

2.1.2. Track_Rover() The Track_Rover() function will allow the camera mounted on the Base Station to autonomously track the Mars Rover while it is in the competition area.

2.1.3. Identify_Target() This function identifies the target rocks based on their color.

2.1.4. Master_Control() The Master_Control() will allow the pilot to decide which functions are enable or disabled.

3.2 Marketing Requirements

1. The Mars Rover must be wirelessly accessible.

2. The components must be modular for easy repair.

3. The cost must be kept under the cap set by Dr. Klink.

4. Weight must be maintained.

5. Base Station add-on should be kept under five kilograms.

6. Technology versus price must be better than competitors.

7. The pilot interface must be user friendly.

8. The encrypted VPN must be easily traversed.

9. The system must be made compatible with further add-ons.

3.3 Engineering Requirements

1. The VPN must include all of the routers used within the Mars Rover and Base Station.

2. The Pilot Interface must be able to switch to different camera views based on the pilot's needs.

3. The Base Station must be kept under maximum weight described above.

4. The Base Station add-on must be able to extend its tower up to two meters.

5. Base Station antenna needs to be able to transmit/receive signals from Mars Rover.

6. Camera installed on Base Station should autonomously follow progress of the Mars Rover and pan for “space rocks.”

3.4 Mapping of Marketing to Engineering Requirements

The following table shows which Engineering Requirements can be mapped to each Marketing Requirement.

Marketing Requirement #	Engineering Requirement #	Justification
1	1, 4, 5	The Rover's need for wireless accessibility is not possible without the routers and the arm
2	1,3,4	Modular parts allow for easy replacement and repair
3	3	Light-weight parts are generally less expensive materials
4	3	Using light-weight materials will contribute less to the total weight of the base station
5	1,3,4,5,6	Each part or aspect of the design must be added with weight in mind
6	1,3,4,5,6	Each part or aspect of the design must be added with cost in mind
7	1,2,5,6	All communications and camera focused design aspects must aid the pilot
8	1,2	Pilot must be able to access camera, router, and rover files with ease if needed.
9	1,2,3,4,5,6	All base station aspects must be able to be upgraded and support additional features.

Table 1: Mapping of Engineering Requirements to Marketing Requirements

3.5 Requirements Trade Offs

The following table shows the relationships between the Marketing Requirements and the Engineering Requirements. An arrow pointing up suggests that the relationship is positive, while a downward pointing arrow denotes an inverse relationship.

	Wirelessly Accessible	Modular	Low-Cost	Under 5 kg	User-Friendly Interface	Encrypted VPN	Compatible with Future Add-Ons
VPN Handles all Communications	↑		↓		↓	↑	↑
Interface Can Switch Camera Views					↑	↓	↑
Light Weight		↑	↑	↑			↑
Arm Extends Two Meters	↑	↓		↓			↓
Arm Transmits Signal	↑					↑	
Camera Task Options					↑		↑

Table 2: Engineering and Marketing Requirement Trade-Offs

3.6 Engineering Requirements Trade-Offs

The following table provides insight into which Engineering Requirements need to be sacrificed to an extent for the benefit of another requirement. An “X” denotes that the pair of requirements is considered a trade-off.

	VPN Handles all Communications	Interface Can Switch	Light Weight	Arm Extends Two Meters	Arm Transmits Signal	Camera Task Options
VPN Handles all Communications					X	
Interface Can Switch Camera Views						X
Light Weight				X	X	
Arm Extends Two Meters					X	
Arm Transmits Signal						X
Camera Task Options						

Table 3: Engineering Requirements Trade-Offs

3.7 Constraints

The following sections will describe any constraints for the Mars Rover.

3.7.1 Economic

The cost of the Mars Rover will take into account any additional software or hardware that is added on this year. The hardware will include new wiring for the use of making the Mars Rover sectionalized. The Base Station will also affect the cost since it will be built for the first time this year. Also the additional camera mounted on the tower of the Base Station add-on will be factored in. The software for the VPN and Pilot Interface will be needed to be calculated.

3.7.2 Environmental

The only environmental constraints will be during testing and the possibility of use on Mars. For this constraint, minimal emissions will be met by using batteries to power the Mars Rover.

3.7.3 Ethical and Legal

The Mars Rover will need to advertise any backing that is given by companies in terms

of free use of software or hardware.

3.7.4 Health and Safety

The system will meet any government requirements to keep emissions at a minimal for use around workers. The wiring of the Mars Rover will be done to keep any occurrence of accidental electrical shock negligible.

3.7.5 Manufacturability The Mars Rover includes several custom manufactured parts. These include the Pilot Interface and the Base Station. The major components of these are not custom parts such as the routers.

3.8 Standards

3.8.1 Safety

Safety precautions for the electrical systems used in the Mars Rover are done to keep accidental electrical discharges and shocks from bare wires kept to a minimum.

3.8.2 Data Formats

The VPN and Pilot Interface programs will be written in C-Sharp. The other programs used to control the Mars Rover will be written in some variant of the programming language C.

2.5.3. Programming Languages

The programming languages used for the Mars Rover will include variations of C and will also utilize the Processing language.

4.0 System Design

4.1 Overall Architecture of the System

The overall architecture of the Mars Rover Base Station is a combination of electrical, mechanical, and computer subsystems. These systems work together to provide the optimal support for the Mars Rover and its pilot. The functionality of the base station includes reforming the entire communications network for the robot, giving the pilot more viewing angles and data to view, and providing a User Interface (UI) for the pilot.

The main priority is to enable an improved communications system from previous years. In the past, a simple Verizon 4G data card was placed on the on-board computer of the robot,

essentially making the robot a roving mobile hotspot. The only issue with this concept was, in the competition field, the rover would lose signal as it traversed through the “lunar bins,” deep valleys within the Rock Yard. Cellular service could not reach these spots efficiently enough for the rover to communicate with the home base computing station. The base station design will allow for a camera and panning antenna to be permanently raised approximately two meters into the air. The antenna will broadcast the cellular signal from an industrial 3G/4G router. Software will be written so that the antenna will follow the rover and provide a boosted cellular signal, even when the robot is driving within the valleys of the Rock Yard.

The base station itself will include a plastic casing as the base, a carbon-fiber extendable arm with a camera and antenna attached, and a pulley system that will be used to extend the arm. A pneumatic cylinder will be used to initially raise the arm and partially extend a section, once the robot has moved from its starting location. Nylon will be attached to the robot, and as it begins to drive away, the nylon will utilize the pulley system and cause the last sections of the arm to extend. The prototype of the base station casing and arm are shown in the following SolidWorks figures:

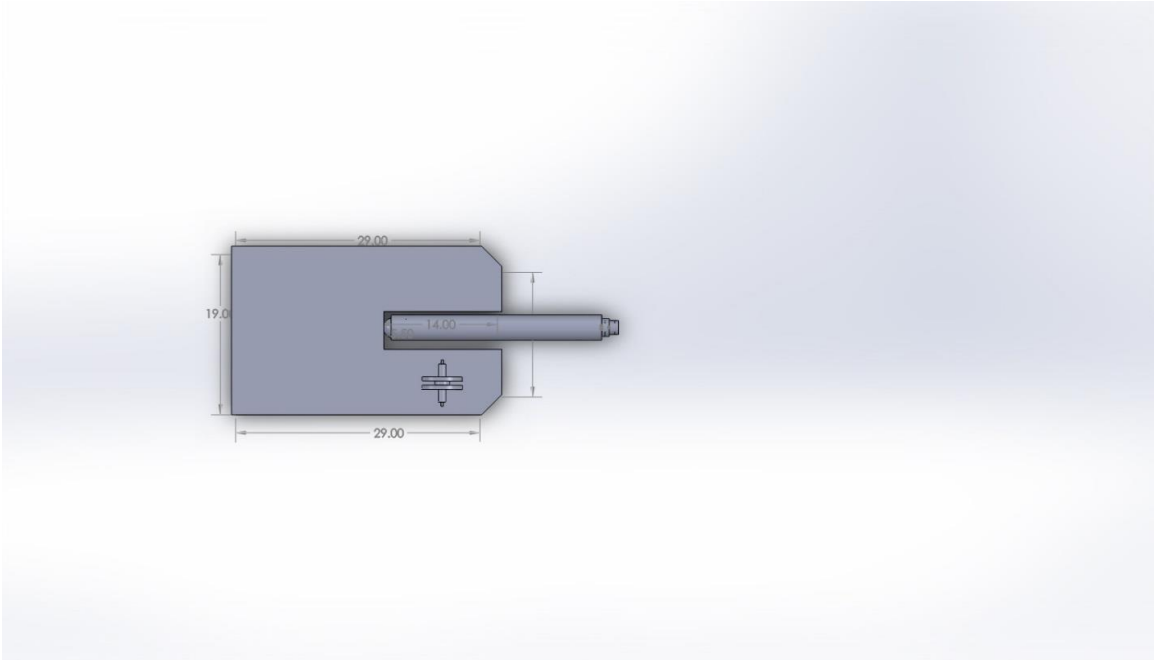


Figure 2: Initial Starting Point of Base Station

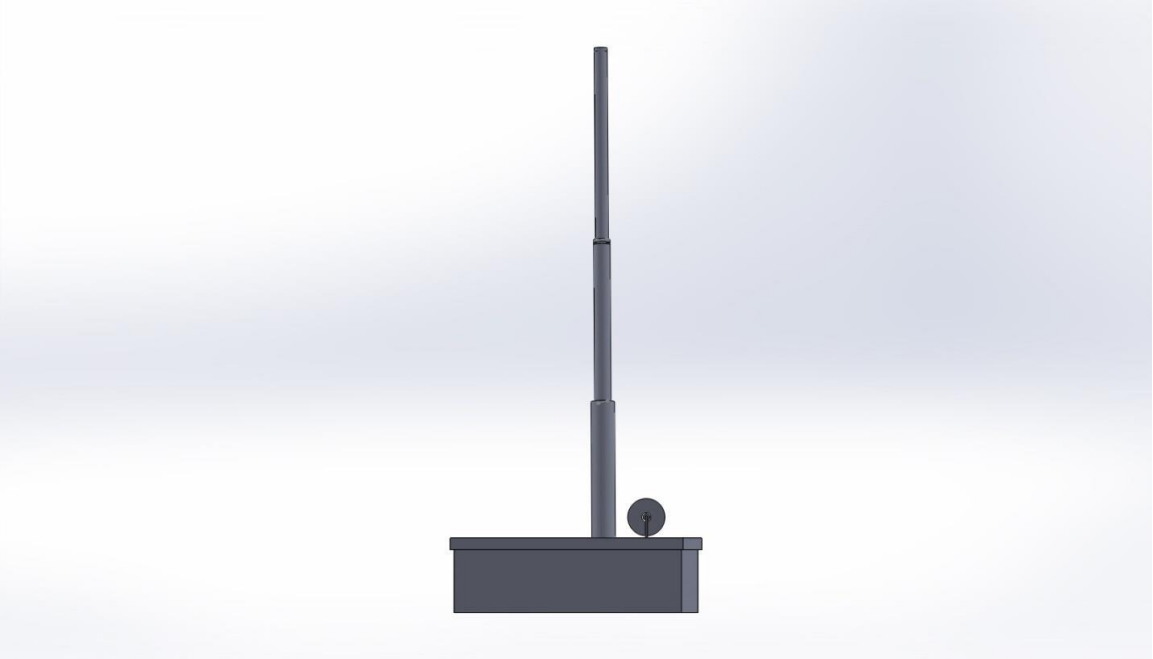


Figure 3: Side-View of Raised Base Station

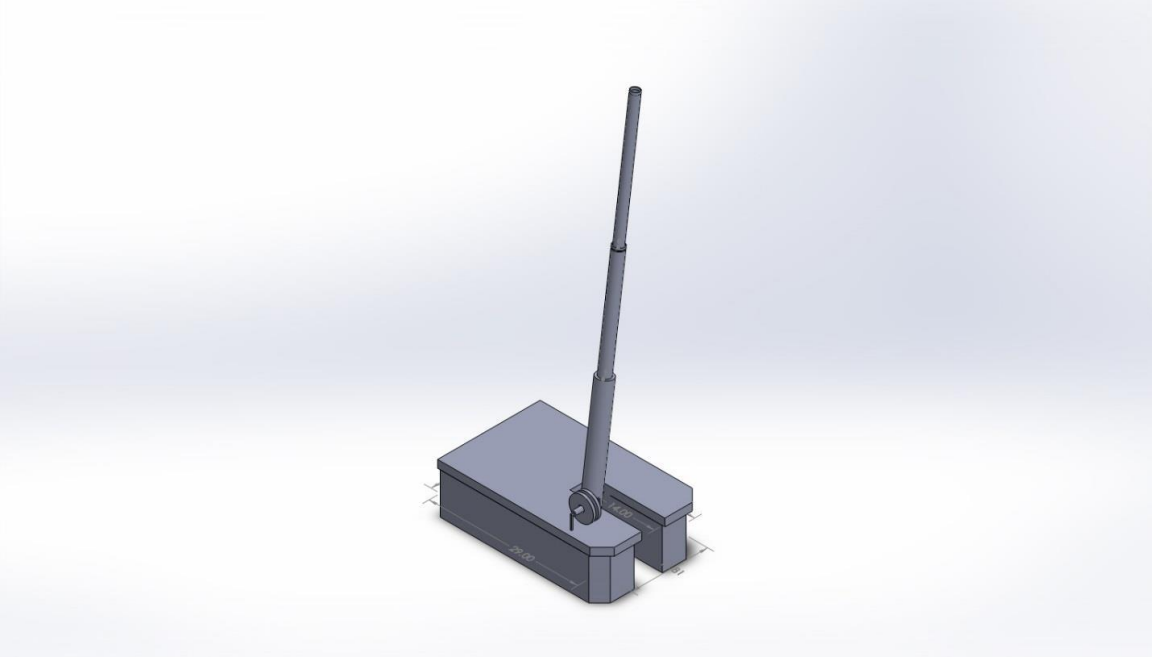


Figure 4: Overview of Raised Arm

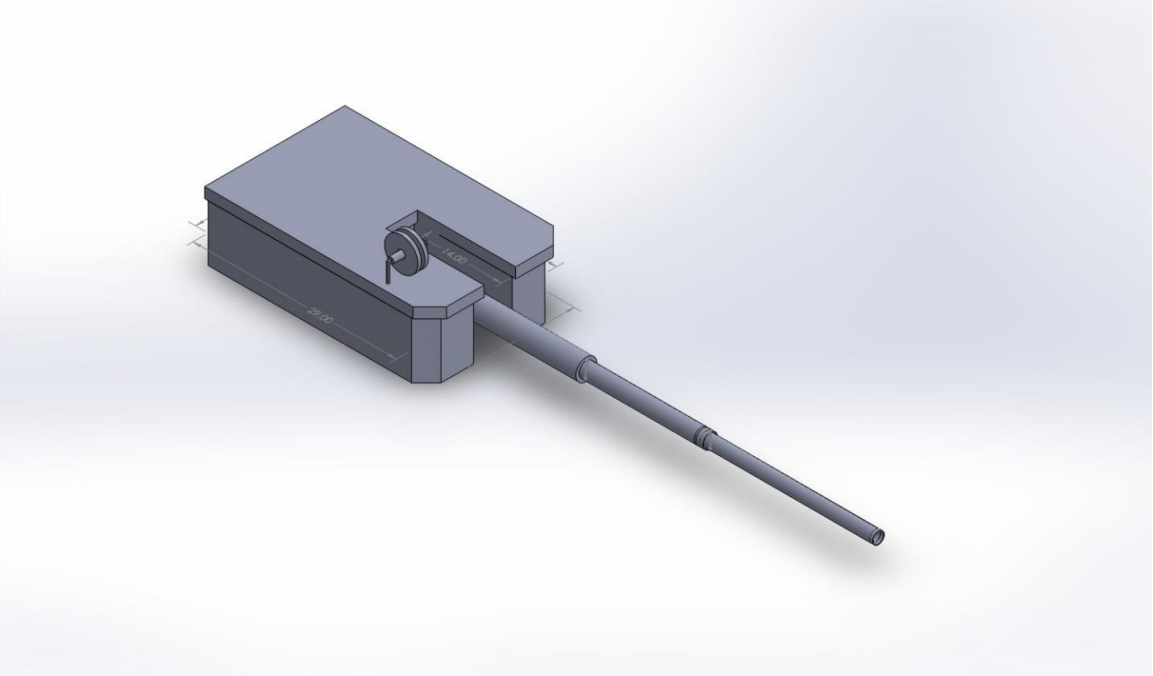


Figure 5: Scaling of Arm to Base Station

The antenna and camera will be attached to the top of the arm of the base station. The antenna is to be used to strengthen the cellular signal, while the camera will have a multitude of uses for the pilot. A subsystem that is present within our communications network will be a Virtual Private Network (VPN). The VPN will utilize the cellular signal and allow all connected members (i.e. the base station, rover, and the home server at WVU) to access the files of the robot or base station so that changes can be made remotely during the competition. The VPN will be constructed by opening and forwarding the ports on the 3G/4G router. This will allow the pilot to have a virtual presence and access the files and programs in the on-board computer of the rover. A CradlePoint ARC MBR1400 is the proposed router for to stream the 3G/4G wireless signal for the base station and the robot.

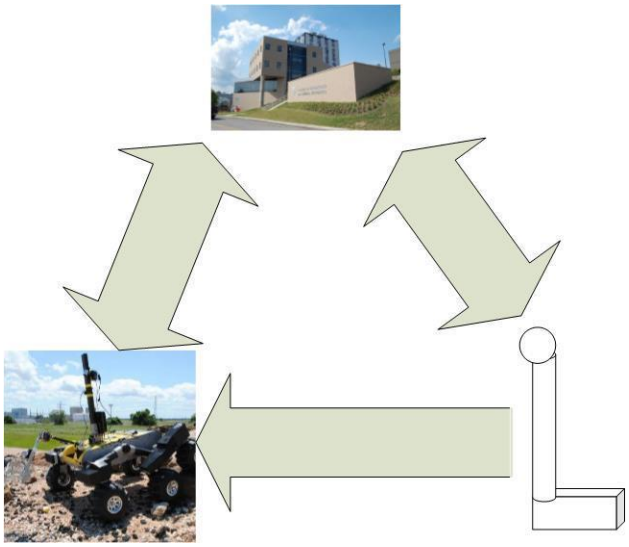


Figure 6: Data Path Within the Virtual Private Network (VPN)

ARC MBR1400 Integrated Mobile Broadband Router

Key Features and Benefits

Internet Access and Device Connectivity

- Integrated high-speed 3G/4G modem – see attached specifications
- 5 Ethernet 10/100/1000 LAN/WAN ports for local devices or landline Internet
- WiFi (802.11 a/b/g/n) supports up to 128 connections at a time

Business Continuity

- Automatic failover to wireless WAN connection when wired WAN disruption occurs, automatic failback when wired WAN connection is restored
- Load balancing across multiple wired and wireless WANs for more bandwidth
- Proactive alerts when failover occurs through Enterprise Cloud Manager
- VRRP for enterprise router redundancy (hardware version 2.0 only)

Flexibility

- First-time and advanced setup wizards for easy, swift, and secure setup
- One-page dashboard to view router status and configuration
- Remote management with CradlePoint Enterprise Cloud Manager
- SNMP v1/2c/3 and CLI over SSH
- Four SSIDs, with individual security and QoS settings, to separate critical traffic or create a public WiFi hotspot with a captive portal (terms of service, ads, etc.)
- "WiFi as WAN" mode enables use as a WiFi repeater, WiFi Bridge, or as a WiFi-to-Ethernet adapter for Ethernet-enabled devices
- Multiple Ethernet ports in LAN or WAN mode (failover, load balancing, etc.)
- Data usage management and alerts to monitor data usage and avoid overages
- LAN/WAN Affinity to assign specific LAN traffic to a WAN
- Serial console available for out-of-band management of another device (with USB-to-serial cable)
- Enterprise routing protocols: BGP, OSPF, RIP*
- Advanced diagnostics tools including: topdump, netfilter, traceroute
- Network Mobility (NEMO) support for session continuity in mobile networks**
- IPv6 support
- Advanced APN management, roaming control, and ability to force 3G or 4G bands

Security

- IPsec VPN (up to 20 concurrent sessions) with GRE Tunneling option, also supports passthrough VPN connections (IPsec, L2TP, PPTP)
- WEP, WPA, WPA2, and AES encryption for secure WiFi
- SPI (stateful packet inspection) firewall and NAT (network address translation) to prevent unwanted access to connected computers
- Advanced security mode and reporting to facilitate PCI-DSS compliance
- Variety of security features (URL filtering, IP & traffic filtering, DMZ, port forwarding) for safer Internet access
- 802.1Q VLAN support to isolate, segment, and secure your network

Service, Support, and Warranty

- CradleCare Premier 1, 2, 3, and 5 year Enterprise Support Agreements available: 24/7 technical support, software upgrades, and advanced hardware exchange
- Limited 1 year warranty included: access to software updates and hardware repair or replacement – 2, 3, and 5 year warranty extensions available
- CradleCare Site Survey and Installation services offered for rapid deployment

Specifications

WAN Wireless WAN modem, 10/100/1000 Ethernet ports (cable/DSL/T1/satellite modems), WiFi (as WAN) 3x3 MIMO "N" 2.4 GHz or 5 GHz (802.11 a/b/g/n)

LAN WiFi (802.11 a/b/g/n), five 10/100/1000 Ethernet ports (WAN/LAN switchable), serial console support w/ USB-to-serial adapter

TEMPERATURE 0°C to 40°C (32°F to 104°F) operating
-20°C to 70°C (-4°F to 158°F) storage

RELATIVE HUMIDITY (non-condensing) 10% to 85%, operating
5% to 90%, storage

SIZE 9x5.1x1.6 in (230x130x40 mm) or 9x7.25x1.6 in (230x185x40 mm)

CERTIFICATIONS FCC, WiFi Alliance, CE, IC, carrier certifications

WIFI POWER Transmit power: 25 dBm typ for all modes; receive sensitivity: -69 dBm typ (11n), -72 dBm typ (11g), -84 dBm typ (11b)

What's In The Box

- ARC MBR1400 with integrated business-class wireless WAN modem
- External 3G or 4G mobile broadband modem antennas (2) (SMA) w/ multiplexing for GPS (on some models), finger tighten only
- External high-gain WiFi antennas (3) reverse SMA (5 dBi, 2.4 GHz), finger tighten only
- 12V / 1.5A power supply
- Quick Start Guide with warranty information

Requirements

Internet Service Active mobile broadband plan with cellular provider or Ethernet-based Internet connection (DSL, Cable, T1)

Browser (to configure router) Minimum of Firefox v2.0, Internet Explorer v7.0, Chrome, or Safari v1.0

Router Details

WAN Security NAT, SPI, ALG, inbound filtering of IP addresses, port blocking, service filtering (FTP, SMTP, HTTP, RPL, SNMP, DNS, ICMP, NNTP, POP3, SSH), protocol filtering, WAN ping (allow/ignore)

Redundancy and Load Balancing Failover/failback with 4G, 3G, Ethernet with rule selection, advanced load balancing options (round robin, spillover, data usage, rate), WAN failure detection, VRRP*

Intelligent Routing UPnP, DMZ, virtual server/port forwarding, routing rules, NAT-less routing, wired or wireless WAN-to-LAN IP passthrough, route management, per-interface routing, content filtering, IP filtering, website filtering, per-client Web filtering, local DHCP server, DHCP client, DHCP relay,* DNS, DNS proxy; ALGs: PPTP, L2TP, PPPoE passthrough, IPsec passthrough, FTP (passive), FTP (active), SIP, TFTP, IRC, MAC address filtering, Dynamic DNS, LAN/WAN affinity, VLAN support (802.1Q), STP,* enterprise routing protocols:* BGP/OSPF/RIP, multicast proxy support,* IP setting overrides, IPv6

Management CradlePoint Enterprise Cloud Manager: cloud-enabled management and application platform (subscription-based); web-based GUI (local management), optional RADIUS or TACACS+ username/password; remote WAN web-based management w/ access control (HTTP, HTTPS); SNMP v1, v2c, & v3; CLI over SSH, SSH to serial, SSH to telnet; API; one-button firmware upgrade; modem configuration, update, and management; modem data usage w/ alerts, per-client data usage; custom AT scripting to modems

Performance & Health Monitoring WiPipe™ advanced QoS with traffic shaping, with DSCP/DiffServe QoS, Modem Health Management (MHM) improves connectivity of modem, SSID-based priority, WAN port speed control, several levels of basic and advanced logging for troubleshooting

VPN (IPsec) Tunnel, NAT-T, and transport modes; connect to CradlePoint, Cisco/Linksys, CheckPoint, Watchguard, Juniper, SonicWall, Adtran and others; certificate support; Hash (MD5, SHA128, SHA256, SHA384, SHA512), Cipher (AES, 3DES, DES); support for 20 concurrent connections, GRE tunneling, multiple networks supported in a single tunnel, site-to-site dynamic VPN with NHRP*

GPS Standalone GPS supported on most models (see attached); GUI mapping as well as local (LAN) or remote (WAN) server logging

Requires hardware version 2.0
**NEMO requires a feature license*

Figure 7: CradlePoint ARC MRB1400 Spec Sheet

The camera that is attached to the top of the arm will be used for two main purposes. The pilot will have the option if he or she would rather view an extra camera feed of the rover in order to see the robot in relation to the rest of the field. For this, a sensor will be placed on the robot and software will be written so that the camera will follow this sensor to provide a back-end view of the rover. The pilot also has the option, if it is desired, for the camera to search for "scoring opportunities" (i.e. brightly colored "moon rocks"). A rock detection algorithm has already been written and used in previous competitions. An adjusted and optimized version of this program will be implemented so that, if the pilot chooses to view this option, scoring opportunities can be viewed on a map that will be on the pilot's monitor. An Axis Network Camera will be used to handle all of these features. The technical specifications for the Axis can be seen below:

Technical Specifications – AXIS P33 Network Camera Series — Outdoor models

Models	AXIS P3363-VE: SVGA, Lightfinder AXIS P3364-VE: 1 MP, Lightfinder AXIS P3364-LVE: 1 MP, IR illumination, Lightfinder AXIS P3384-VE: 1 MP, WDR - dynamic capture, Lightfinder AXIS P3346-VE: 3 MP, multi-view streaming AXIS P3367-VE: 5 MP, multi-view streaming *Note: All models are vandal resistant and support audio and I/O ports* *6 mm and 12 mm as suffix refer to lens model*
Camera	
Image sensor	AXIS P3363-VE: Progressive scan RGB CMOS 1/3" AXIS P3364-VE/-LVE: Progressive scan RGB CMOS 1/3" AXIS P3384-VE: Progressive scan RGB CMOS 1/3" AXIS P3346-VE: Progressive scan RGB CMOS 1/3" (effective) AXIS P3367-VE: Progressive scan RGB CMOS 1/3.2"
Lens	Varifocal, Remote focus and zoom, P-Iris control, IR corrected, Megapixel resolution AXIS P3363-VE/P3364-VE/P3364-LVE 6 mm: 2.5–6 mm, 105°–49° view[a], F1.2 AXIS P3363-VE/P3364-VE/P3364-LVE 12 mm: 3.3–12 mm, 82°–24° view[a], F1.4 AXIS P3384-VE: 3–9 mm, 84°–30° view[a], F1.2 AXIS P3346-VE: 3–9 mm, 84°–30° view[a], F1.2 AXIS P3367-VE: 3–9 mm, 84°–30° view[a], F1.2
Day and night	Automatically removable infrared-cut filter
Minimum illumination	AXIS P3363-VE/P3364-VE 6 mm: Color: 0.1 lux, F1.2, B/W: 0.02 lux, F1.2 AXIS P3364-LVE 6 mm: Color: 0.12 lux, F1.2, B/W: 0.03 lux, 0 lux with IR illumination on AXIS P3363-VE/P3364-VE 12 mm: Color: 0.15 lux, F1.4, B/W: 0.03 lux, F1.4 AXIS P3364-LVE 12 mm: Color: 0.18 lux, F1.4, B/W: 0.04 lux, 0 lux with IR illumination on AXIS P3384-VE: Color: 0.5 lux, F1.2, B/W: 0.08 lux, F1.2 with dynamic capture Color: 0.15 lux, F1.2, B/W: 0.03 lux, F1.2 with Lightfinder AXIS P3346-VE: Color: 0.5 lux, F1.2, B/W: 0.08 lux, F1.2 AXIS P3367-VE: Color: 0.2 lux, B/W: 0.04 lux, F1.2
Shutter time	AXIS P3363-VE/P3364-VE/P3364-LVE: 1/24500 s to 2 s with power line frequency 50 Hz, 1/29500 s to 2 s with power line frequency 60 Hz AXIS P3384-VE: Dynamic capture: 1/192 s to 1/37 s with power line frequency 50 Hz, 1/231 s to 1/44 s with power line frequency 60 Hz Lightfinder: 1/24500 s to 2 s with power line frequency 50 Hz, 1/29500 s to 2 s with power line frequency 60 Hz AXIS P3346-VE: 1/35500 s to 1/6 s AXIS P3367-VE: 1/28000 s to 2 s
Camera angle adjustment	AXIS P3363-VE/P3364-VE/P3364-LVE: Pan 360°, tilt 170°, rotation 340° AXIS P3384-VE/P3346-VE/P3367-VE: Pan 360°, tilt 160°, rotation 340°
Video	
Video compression	H.264 Baseline and Main Profile (MPEG-4 Part 10/AVC) Motion JPEG
Resolutions	AXIS P3363-VE: 800x600 (SVGA) to 160x90 AXIS P3364-VE/P3364-LVE/P3384-VE: 1280x960[b] (approx. 1.3 MP) to 160x90 AXIS P3346-VE: 2048x1536 (3 MP) to 160x90 AXIS P3367-VE: 2592x1944 (5 MP) to 160x90
Frame rate	AXIS P3363-VE/P3364-VE/P3364-LVE/P3384-VE: 25/30 fps with power line frequency 50/60 Hz AXIS P3346-VE: 3 MP capture mode: 20 fps in all resolutions; HDTV 1080p (1920x1080) and 2 MP 4:3 (1600x1200) capture modes: 30 fps in all resolutions AXIS P3367-VE: 5 MP capture mode: 12 fps in all resolutions; and capable of all AXIS P3346-VE capture modes
Video streaming	Multiple, individually configurable streams in H.264 and Motion JPEG, Controllable frame rate and bandwidth, VBR/CBR H.264

Figure 8: Specification Sheet for Axis Camera

A microcontroller, most likely Arduino or Raspberry Pi, will be used to control all aspects of the actual base station. The microcontroller, along with the camera, router, and the pneumatic cylinder will be powered by a 14.8 Volt Lithium Polymer battery. Software for the microcontroller is to be written so that the data, in the form of the video stream, will be compressed and transmitted through the VPN by way of the router.

The last aspect of the system is the Graphical User Interface (GUI), in which the pilot will be

able to view camera angles and/or rock proximity. In past competitions, the pilot only had one monitor that displayed the two on-board camera views. This version can be viewed in Figure Seven. If the pilot chooses to utilize the rock detection feature, a map-like display will show the location of the rocks in relation to the base station at the starting point. The pilot may also just want another perspective of the rover that will display where the robot has been. For this feature, the pilot would need to specify it, rather than the rock detection, in a drop down menu. The monitor will then display the camera view from the base station. The sensor on-board the robot will allow the camera to pan and follow the rover and send the video signal to the monitor no matter the position of the rover on the field.

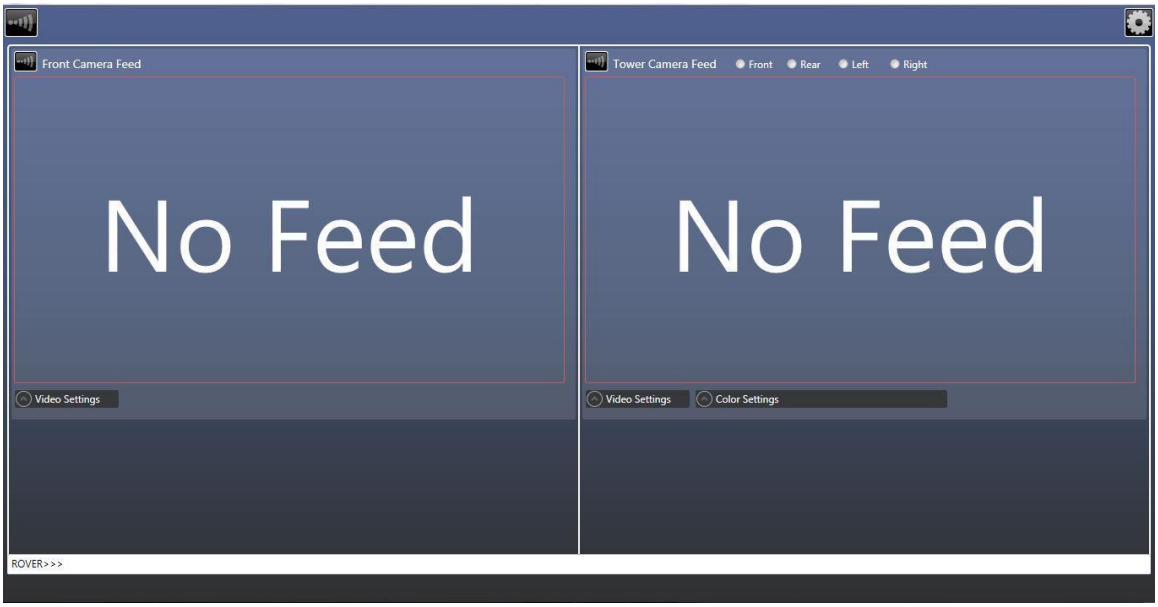


Figure 9: Previous User Interface for Rover Pilot

4.1.1 Context Diagram

The following figure depicts the context diagram for the Base Station.

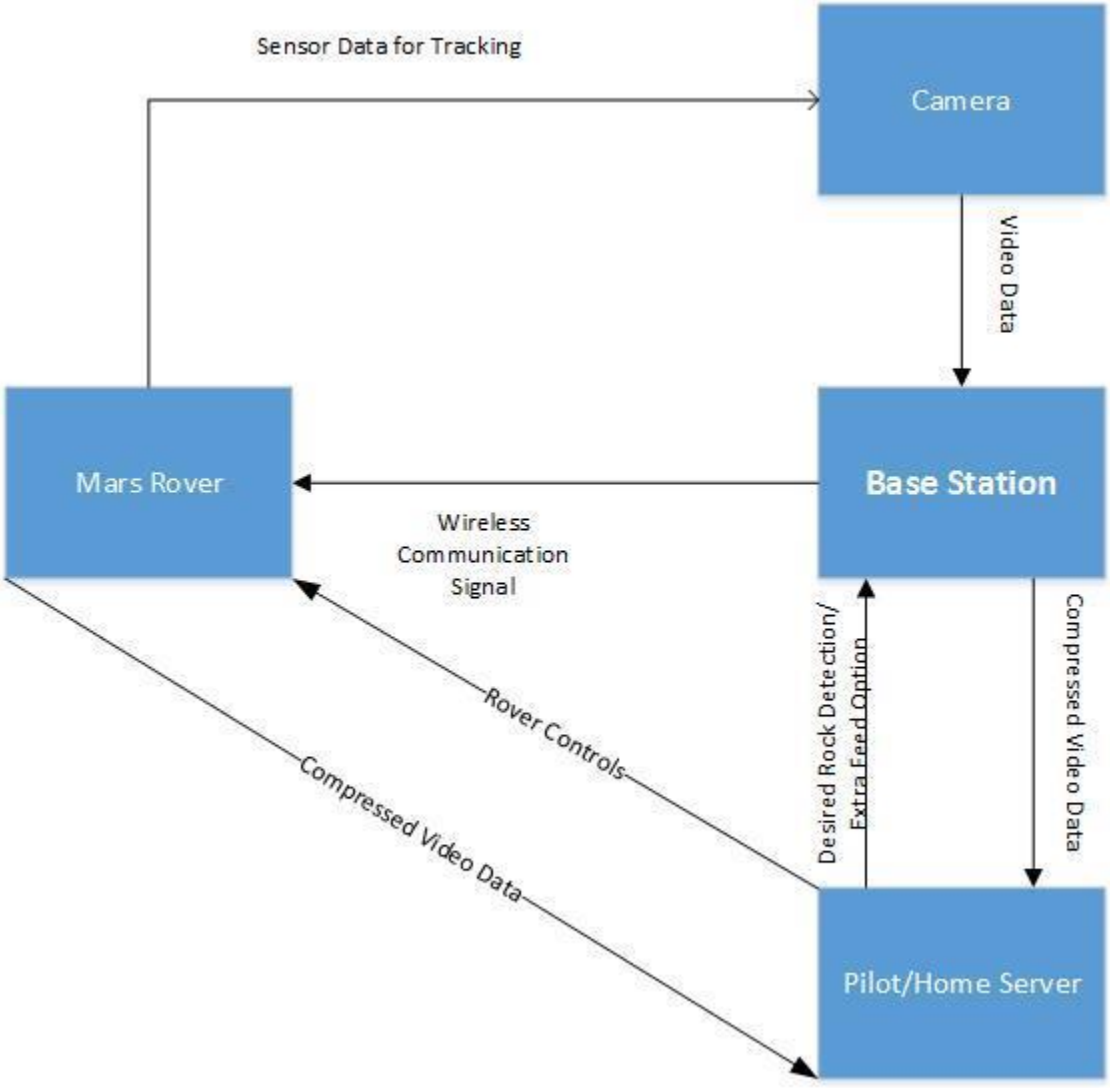


Figure 10: Context Diagram for Base Station

4.2 Use Cases

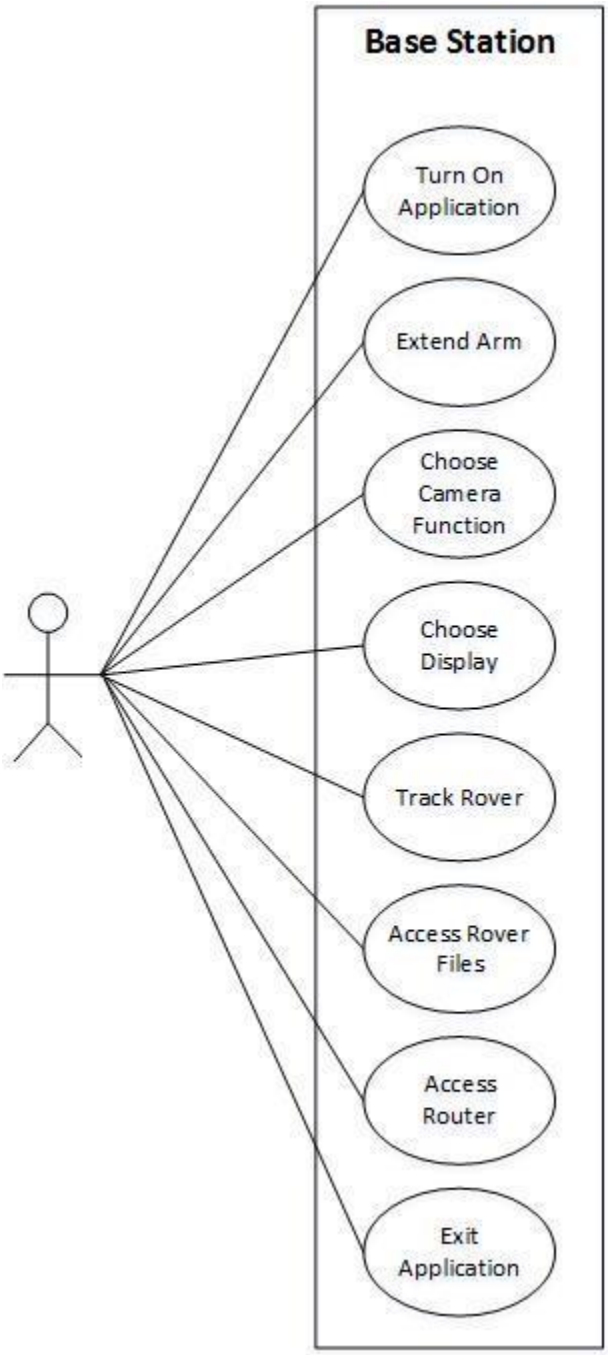


Figure 11: Use Case Diagram

Table 4: Turn On UI Use Case

Use-Case	Turn on User Interface Application
Participant(s)	Pilot, Co-Pilot
Description	Pilot begins the application and blank camera feeds are available on the monitor.
Stimulus	Pilot runs the .app file
Response	The application will run, allowing all camera feeds and data for the base station to be viewed in the UI.
Exceptions	Software not up to date

Table 5: Extend Arm Use Case

Use-Case	Extend Arm
Participant(s)	Pilot, Co-Pilot
Description	Base Station Arm extends via pneumatic cylinder once rover has moved from starting point.
Stimulus	Pilot moves robot from starting location
Response	Sensor tells the Base Station to raise arm and initiates cylinder pneumatics and pulley system
	Sensor/Cylinder not enabled or fails

Exceptions	

Table 6: Choose Camera Function Use Case

Use-Case	Choose Camera Function
Participant(s)	Pilot, Co-Pilot
Description	Pilot chooses whether to use the camera to follow the robot or pan for rocks.
Stimulus	Pilot chooses from drop down menu
Response	Corresponding functions will be called to perform desired task.
Exceptions	Neither task is desired

Table 7: Choose Display Use Case

Use-Case	Choose Display
Participant(s)	Pilot, Co-Pilot
Description	Pilot uses the UI to select the display that is desired
Stimulus	Pilot chooses desired display type via

	menus/buttons on UI
Response	Corresponding display will appear on monitors
Exceptions	No display is desired or required

Table 8: Track Rover Use Case

Use-Case	Track Rover
Participant(s)	Pilot, Co-Pilot
Description	Pilot desires for camera to provide a back-end view of rover
Stimulus	Pilot selects function on UI
Response	Camera follows sensor on robot and provides camera feed.
Exceptions	Function is not desired Rover is in “pit,” preventing camera angle

Table 9: Access Rover Files Use Case

Use-Case	Access Rover Files
Participant(s)	Pilot, Co-Pilot
Description	Pilot accesses files on rover computer via VPN
Stimulus	Pilot enters network, selects desired file, allowing for

	viewing/modification
Response	Files are updated simultaneously on rover
Exceptions	Desired file is currently in use

Table 10: Access Router Use Case

Use-Case	Access Router
Participant(s)	Pilot, Co-Pilot
Description	Pilot accesses router configuration via VPN
Stimulus	Pilot enters network, selects desired configuration, allowing for viewing/modification
Response	Router will be updated in real-time
Exceptions	Specific configuration is locked by manufacturer

Table 11: Exit Application Use Case

Use-Case	Exit Application
Participant(s)	Pilot, Co-Pilot
Description	UI is closed and communication from Home Base ceases

Stimulus	Pilot exits application
Response	Camera data is no longer sent to Morgantown
Exceptions	Pilot accidently exits UI, which would bring up a confirmation message

4.3 User Interface Specifications

The User Interface will mainly be a simple GUI run by Visual Studio, written in C#. The UI will open up two windows, one to serve the Base Station camera, and one to view the on-board cameras of the robot. The main component of the design will be focused on the Base Station camera. The previous UI, as seen in Figure Seven, will be updated per the pilot's request and utilize the second window.

The window of the UI that interfaces with the Base Station will include one window, a menu, and a map. The menu will allow the pilot to choose the desired function of the camera, whether it is to track the rover, serve as a rock detection system, or leave the camera in a power saving "sleep" mode. If the tracking option is chosen, the window will show the camera feed from the Base Station camera that will follow the rover as it traverses the "Rock Yard." The rock detection option will leave the camera window empty and utilize the map on the GUI. As the camera scans for rocks, the location of any found rocks, relative to the location of the Base Station, will be provided on the map. The power saving option will shut down the camera and conserve battery power for the Base Station.

The second window of the GUI will provide a revamped interface for the rover controls. There have been numerous troubles and complaints with the previous control's interface. A list of complaints from the pilot of the 2013 competition include:

- Only mast camera and fisheye camera views were available
- The mast camera was replaced the day before the competition, leaving no time for testing with software
- Video feeds were extremely grainy
- Issues with Microsoft drivers prevented the use of more than two cameras

- Too much data coming back with little quality

- The delay of the video feed ranged from three to fifteen seconds, if the video feed came through at all

All of the above issues will be addressed by an updated GUI that will be designed for the pilot. Most of these issues will be solved through testing and the improved communications network. The goal is to have four cameras on-board the rover, a mast camera, a fisheye camera, and two cameras on each side of the robot. All four camera feeds will be compressed and carried over the communications network and appear in four separate screens on the pilot's UI. The interface itself will simply consist of four video screens that the pilot will be able to utilize as he or she navigates the robot.

4.4 Data Flow Diagrams

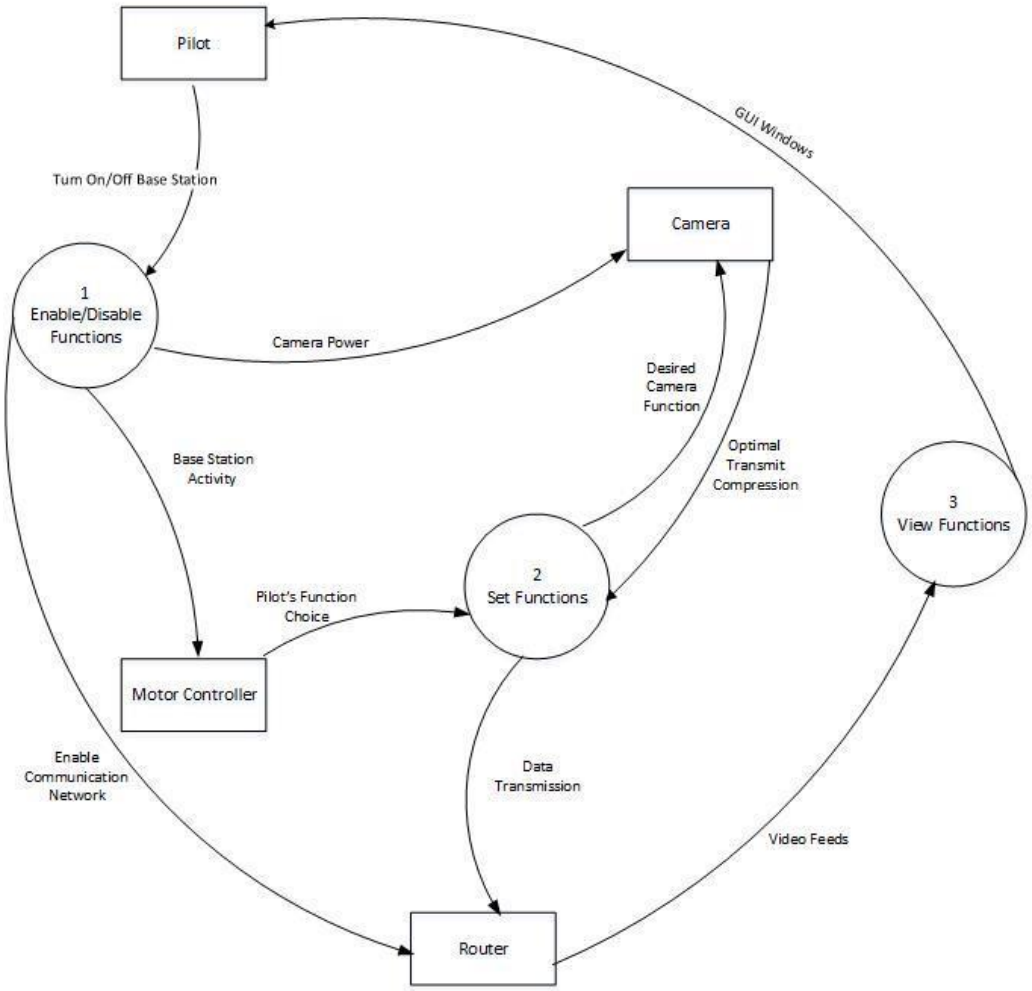


Figure 12: Dataflow Diagram of Base Station

4.5 State Transition Diagram

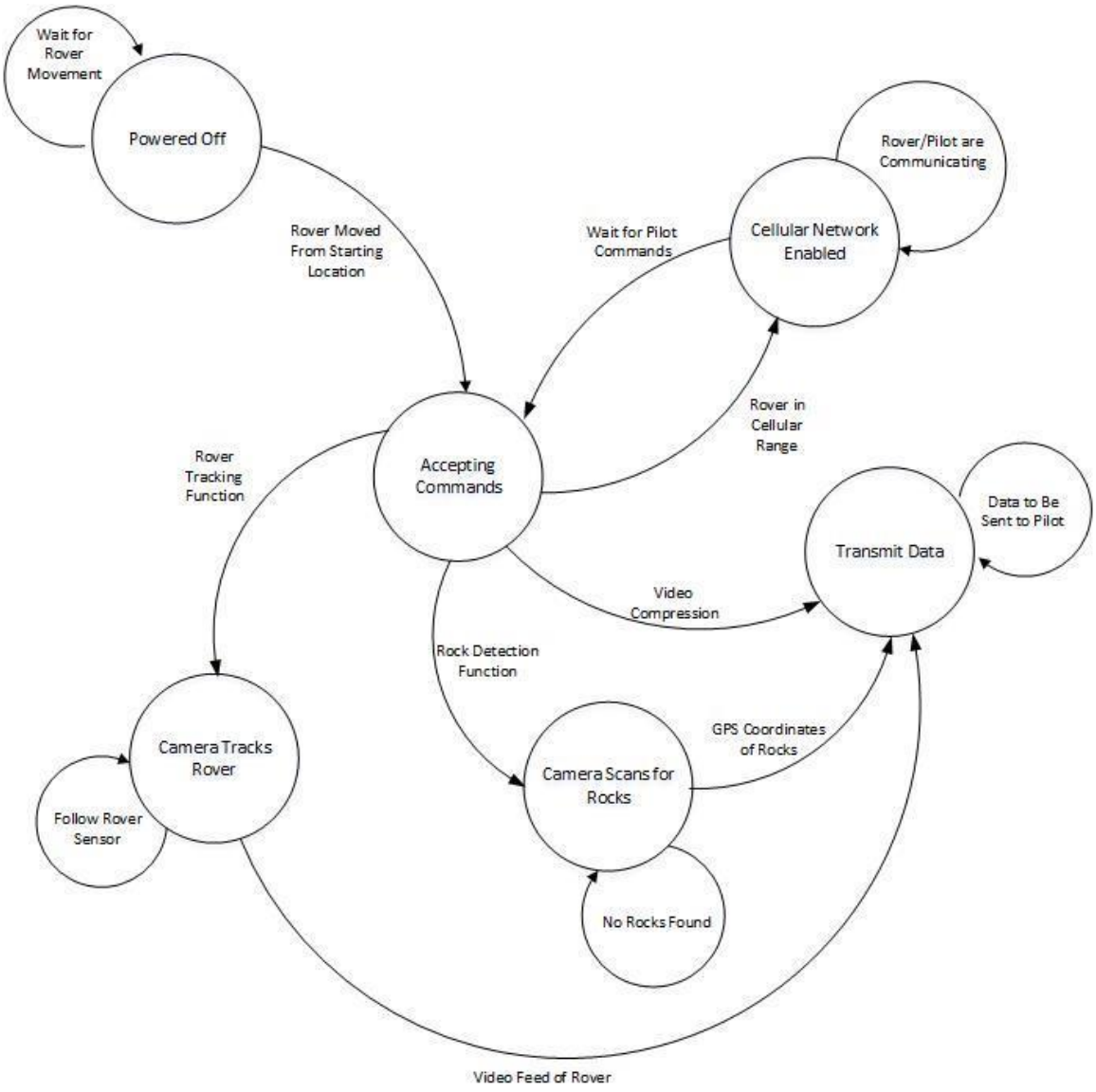


Figure 13: State Diagram of Base Station

4.6 Circuit Diagram

The electrical system of the base station is given below. The spacing will be similar to what is shown. The battery will power all equipment contained within the base station, which includes the microcontroller, camera, and router.

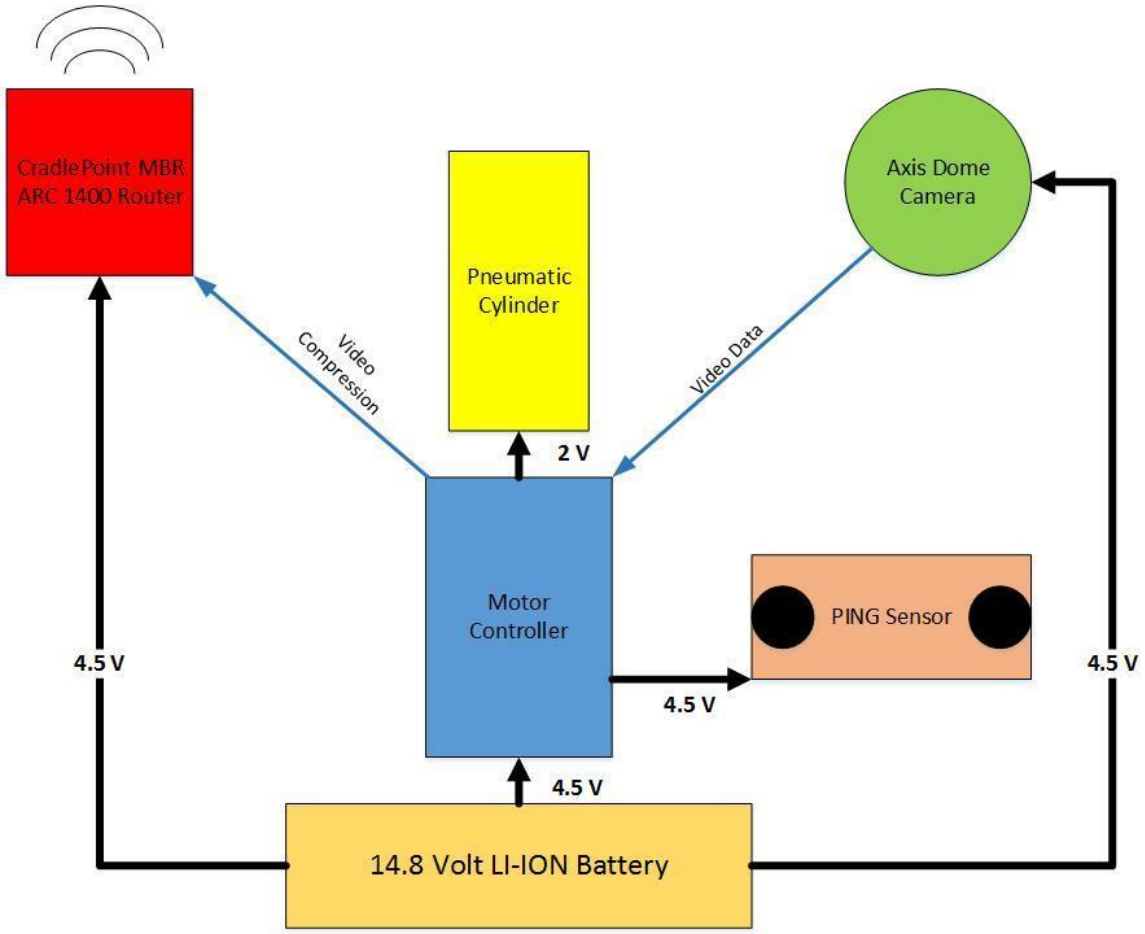


Figure 14: Circuit Diagram Overview

4.7 Parameter Analysis

The biggest parameter analysis that was to be done involved determining the point at which the pneumatic cylinder would support the arm of the base station by using the diagram below and the center of mass equation. It has been determined that a point that is roughly 0.5 meters up the carbon-fiber arm will prevent the base station from tipping.

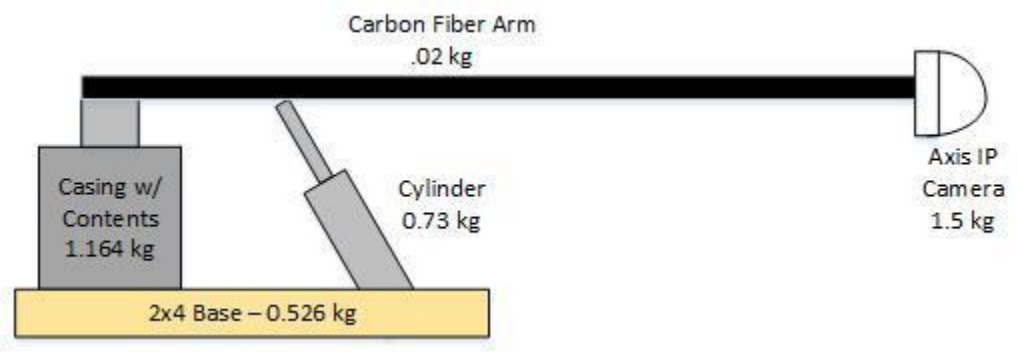


Figure 15: Center of Mass Analysis

5.0 Test Plans

5.1 Component Testing

Camera:

The camera will be tested to insure that is pans to either follow the rover or search for “space rocks.”

Lift Arm:

The lift arm will be tested to ensure that it raises to its vertical position and then raises. The arm will raise to its vertical position with a pneumatic lift and then extend upward using a motor and pulley.

Pneumatic Cylinder:

The cylinder will be tested to ensure that it raises the arm to the appropriate height once the signal is received from the PING sensor, essentially telling it that the robot has moved from above the base station.

Batteries:

The batteries will be tested to ensure that they contain a charge and are at the appropriate voltage. Batteries must hold a charge long enough to complete the competition.

Router:

The router must be tested to ensure that the VPN communications can be accessed by the pilot and that the cellular signal can reach the rover at distances matching those in the competition.

5.2 Integration Testing

The integration tests will consist of using all the components together and ensuring everything happens in the correct order. For example, the arm must lift to its vertical position before it extends upward.

5.3 Acceptance Testing

Set Speed :

Goal	Current State	Expected Output
Valid	• Previous speed • motor on	Motor changes speed
Invalid	Motor off	Warning message (Motor is off)

Table 12: Set Speed Acceptance Tests

Set Direction:

Goal	Current State	Expected Output

Valid	• Previous direction • motor on	Change direction
Invalid	Motor off	Warning message (Motor is off)
Invalid	Invalid direction	Warning message (Direction is invalid)

View Voltage:

Goal	Current State	Expected Output
Valid	Valid battery voltage	Voltage is displayed
Invalid	Batteries below operation conditions	System is off

Lift Arm to vertical:

Goal	Current State	Expected Output
Valid	Arm is in horizontal position	Arm is in vertical position
Invalid	Arm is in vertical position	Warning Message (Arm is already lifted to vertical)

Extend arm:

Goal	Current State	Expected Output
Valid	Arm is in vertical position	Arm is in horizontal position

Invalid	Arm is in horizontal position	Warning Message (Arm is already horizontal)

Goal	Current State	Expected Output
Valid	• Arm is vertical • Arm is compact	Arm extended
Invalid	• Arm is horizontal • Arm is compact	Warning message (Lift arm to vertical)
Invalid	• Arm is horizontal • Arm is extended	Warning message (Arm is already extended)

Lower arm:

Goal	Current State	Expected Output
Valid	• Arm is vertical • Arm is extended	Arm is compacted down
Invalid	• Arm is horizontal	Warning message (Arm is compact and in

horizontal position)

5.4 Failure Mode Analysis

Failed Component	State	Effect(s)
Pneumatic lift	Unrecoverable	Arm failed to lift into vertical position
Motor and pulley	Recoverable	Arm is in vertical position but doesn't have a good field of view
Battery	Unrecoverable	Not enough power to operate
Arm breaks	Unrecoverable	Camera is unable to be used
Camera	Recoverable	No video feed from the camera
Weight of base station	Unrecoverable	Above weight limit for the competition
Cradle Point router	Unrecoverable	No communication to the base station

5.5 System Recovery

If the lift fails, then the arm will not be raised to its vertical position and then camera will not be able to be used. If this happens the connection to the rover may be compromised. If

the motor and pulley fail, then the arm will not be able to extend to its maximum height. This camera is not a critical component and the base station may still be able to keep the rover from losing signal. The camera will still be operable, but the camera will not have as high of a view and some of the rock field may not be visible. The batteries are a crucial part of this system. If the batteries fail then the entire base station is just wasted weight. If the camera mount arm breaks then the camera will be not be able to be used and the line of sight with the rover may not cover the entire rock yard. The Cradle Point router is the main component in the base station. Without cradle point there is no way to communicate with the base station. If all communication is lost then the base station is lost and it is a complete failure.

6.0 Project Plan

6.1 Work Breakdown Structure/Milestone

Though each team member has a defined goal and particular part of the project to make it a whole, each member will also assist in other phases of the project. Each objective also serves as a major milestone for the project.

Objective Descriptions:

1. Base Station Design – Design a base station to house the Axis camera and CradlePoint routers that will meet the competition design restrictions.

2. Base Station Fabrication – Construction and assembling of the base station

3. Software Design – Write programs for the microcontroller to control the pneumatic cylinder and the camera.

4. VPN Network Setup – Establish a secure Virtual Private Network, using the routers, with which we can control the rover from remote distances using cellular communications.

5. Rock Detection and GPS Programs – Design software to use the base station camera to track the rover and to pan for “space rocks.”

6. Data Compression – Write a compression program to compress all video and GPS data before transmitting it to the home base.

7. Graphical User Interface – Create a user-friendly interface to assist the operator in controlling the rover’s features and movement.

6.2 Work Assignments/Gantt Chart

The following Gantt chart provides a list of all tasks that were described above and which team members will be focusing on these tasks and for how long. While an individual or group of team members may focus on a specific design objective, the whole team will provide support as often as possible.

#	Task Description	Division of Work						Week															
								January			February					March				April			
		RM	CP	JH	NH	WC	ZH	8th-15th	15th-22nd	22nd-29th	29th-5th	5th-12th	12th-19th	19th-26th	26th-5th	19th-26th	26th-2nd	2nd-9th	9th-16th	16th-23rd	23rd-30th	30th-3rd
1	Base Station Design	0	10	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	Base Station Fabrication	20	0	0	0	0	0	0	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	Software Design	10	5	5	10	5	45	0	0	30	10	10	10	20	0	0	0	0	0	0	0	0	0
4	VPN Network Setup	10	5	5	10	35	5	0	0	10	20	15	25	0	0	0	0	0	0	0	0	0	0
5	Rock Detection and GPS	20	10	60	10	10	10	0	0	10	10	30	20	20	30	0	0	0	0	0	0	0	0
6	Data Compression	5	20	5	40	5	5	0	0	5	40	0	5	10	20	0	0	0	0	0	0	0	0
7	GUI	20	40	5	10	10	10	0	0	0	10	20	15	25	25	0	0	0	0	0	0	0	0
	Totals Hours:	85	90	80	80	65	75	10	20	55	90	75	75	75	75	0	0	0	0	0	0	0	0
	Grand Total Hours:	475																					

Table 20: Gantt Chart of Work Breakdown

6.3 Contingency Plan

If any of the above plans cannot be completed, then some of the work may be provided by members of the robotics team as a whole. If not, the order of importance for the objectives are as follows:

1. Network Setup

2. Base Station Fabrication

3. GUI Design

4. Data Compression

5. Camera Functionality

The main goal of this project is to provide the extra components needed to help the robotics team succeed by winning the 2014 RASC-AL Robo-Ops Competition. If they, or Dr.Klink, feel that the an aspect of this design is not worth seeing it through fruition, then it will be adjusted or discarded.

7.0 References

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Appendix One – Procurement List

A procurement list will be provided as soon as possible.

Appendix Two – Project Website

We have not yet completed our project website.

Appendix Three Individual Papers

Individual Papers begin on the following page.

EE 480 Mars Rover Project Individual Research Paper 10-14-13 James Hunsucker

Needs: The needs for this project have been set by experiences from years past in this

competition. Those who judge the competition last year told the team that they loved the physical design of the robot and did not want it to be changed in any major way. So, in order to stick true to the original design our major task is to improve upon the issues that were faulting the team last year.

The major issue that faulted the team's previous attempt was communications. Previously the team had used a Verizon 4G cellular network in order to provide internet to the rover. This is needed in order to have access to the robot's multiple video feeds and to get controls to the rover from Morgantown to Houston. The problem that was presented last year was a loss of communications between the rover and Morgantown. This was due to there being "dead zones" and "lunar pits," in these areas we would lose contact with the rover and it would be left useless. The solution that is our main project is to create a base station. This base station is to prevent any loss of communications so that the team does not come upon the same issues as last year.

Another one of the needs that has been placed upon our team is to develop a web- based application that integrates all of the viewing screens from multiple cameras, a sonar-like GPS tracking system that

gives the location of the rover on the field, and the coordinates of rock deposits for scoring opportunities. Previously the team used commercial software that inadequately met the needs for the rover pilot. This GUI based program is needed to make the rover pilot's job easier. By integrating all of the different viewing screens, the sonar-like GPS positioning system, and the coordinates of the rock deposits the pilot will be at a much greater advantage than in any previous year.

Along with these other needs our group is providing support for all other aspects of the Mars Rover. This support consists of designing, any re-building that needs to occur, and on the spot troubleshooting as the team moves forward. In previous years the team has had to rush to complete the rover in time for the competition. This gave them little to no time for testing before going to Houston. Our group hopes to prevent this need to rush by being there for every

step to complete everything in a timely nature. This will allow the team to know that the rover is the best that it can be for this year's competition. Also in being there for support of the rest of the team we can assure that the base station is completely and properly integrated into any new work that is occurring on the Mars Rover.

Ranking of Needs: All of the needs listed above are necessary to the success of this project; however, the

number one need for this project is the implementation of the base station. The breakdown in communications is what prevented the team last year from being successful. All of the other objectives rely upon this main task. Without the base station for communications there will be no use for the improved user interface. This is still a very important need in terms of successfully performing the tasks set forth for the competition.

In order to guarantee the success of this project in the competition the number one priority is to ensure continuous and strong

communications with the rover. The team plans to do this with the implementation of a base station take the incoming signal cellular and setup a wireless area being emitted from the base station. This is necessary in order to have reliable video feeds that contain minimal lag delivered to the pilot in Morgantown.

The second major priority is to get the GUI program up and running properly. This is of great need to integrate all of the inputs that will be flowing in into one centralized program that will better assist the pilot in maneuvering and completing objectives with the rover. By having the camera feeds and all of the other data routed into one visual location the pilot's performance will be greatly increased. Really these two go hand in hand with each other and are both extremely important needs for this project. However, without the GUI the team would still have a direct camera feed, but the easier we can make the pilot's job maneuvering the rover the better we will do during the competition.

Assisting the rest of the robotics team with building, maintaining, and designing the robot encompasses everything that our team is trying to do. The group is at the robotics team's disposal to improve the performance of the rover in any and every way possible in order to greatly improve our results in the competition in Houston. With this continued support we will

also gain knowledge of the interworking of the rover, so that we can much more efficiently complete our tasks. With this knowledge we will better be able to correctly configure the communications to work robustly between the rover and the base station and back to Morgantown. With our group assisting the robotics team the goal is to get everything completed much sooner than it would be so that the team can spend much more time testing prior to the competition.

Background:

The competition that the team plans to compete in is the RASC-AL

Exploration Robo-Ops Competition. West Virginia University has competed in this event the past two years. The rover has come in fourth in both of these previous years. The Mars Rover is to be designed to operate remotely and to have the capabilities to find and collect specified rocks. The competition is aimed at undergraduate and graduate students consisting of multidisciplinary teams to best build a robot to collect these specified rocks while being remotely operated from the team's home college. The field for testing is located in Houston, TX at the NASA Johnson Space Center's Rock Yard.

The greatest problem that the team from last year faced was a break down in communications. Since the previous team was told by the judges at NASA to not change the physical design of the robot, the main focus of this year's team is to greatly improve the communications.

Other rules of the competition allow the team to have a "pit crew" in Houston to deliver the rover and do any necessary maintenance or modifications on site. The team will not only be

judge on the rover and its performance, but also on the submission a technical paper, a poster presentation, and be able to show that it has an Education and Public Outreach program.

The first year that the team participated in the competition was 2012. At this competition WVU had the heaviest rover, which based upon the rules of the competition meant that they were to go first. This is a disadvantage because the other teams are allowed to observe other teams navigating the course through a video stream that is set up. During WVU's run in the competition the rover became stuck in a crater that was simulated on the field. Because the team did not have adequate time to test this year they were unsure as to how to properly dislodge the rover from this situation. The pilots decided the best option was to rev the rover up to full speed in an attempt to free the rover from the crater. This, unfortunately, caused the servos for the

rear wheels to be maxed out causing mechanical failures that left the robot un-operational.

After the first competition the team decided to redesign the robot in order to no longer have to worry about the pitfalls of the previous year. They adopted a design extremely similar to the design of NASA's Curiosity rover. The idea behind this new redesign was to be able to traverse craters with ease and avoid getting stuck in anyway. The main part of the redesign was the chassis opting for a "rocker-bogie" design. This designs purpose is to be able to transverse rough terrain, including rocks, while maintaining contact with the ground with all six wheels. This allows the rover to withstand a tilt of up to 50 degrees in any one direction.

After these redesigns the team still met problems during the competition. While the rover could now transverse these craters and obstacles there are dead spots in communication.

The example of this is the four cameras mounted to the rover that were supposed give a live video feed to the pilot in Morgantown. There was a twenty second delay on the video and at times it would go completely blank. This long of a delay is crippling to the operator attempting collect the rock samples.

The basis for this year's efforts is to completely revamp the communication process. The team hopes to take the improved body redesign from last year and pair it with a fully functioning communications system to guarantee a working rover for the competition. The idea is to use a 3G/4G router that can then compress the cellular data and transmit it back to Morgantown. With this new communications system the idea is that it will increase bandwidth and the speed at which data is sent and received between the two locations.

Objective:

Each of our objectives that have been determined are based off of the initial needs stated. Clearly with the team wishing to compete in the RASC0AL Robo-Ops Competition the main objective is to win the competition. Any improvement in placement would demonstrate the efforts that WVU has put into this competition are worth the time and dedication of the students working towards this project. Each year so far there have been specific flaws that have prevent WVU from being in the top ranks of the competition. A high placement in this year's competition would bring a much greater respect to WVU's robotics program.

The major objective to fulfill the main object is to build a base station that will vastly improve communications. The base station is to include an extendable shaft that will raise the rock detection camera and the cellular antennas that are to guarantee a good connection to the rover and Morgantown at all times. The steps need to properly implement this base station include implementing motor or some type of pulley system to raise the antenna arm with no exterior input, meaning it cannot be manually raised but a part of the pit-crew. Since this arm will also house a camera for rock detection we need to include a way to rotate the camera when the arm is fully extended. The goal is to integrate this system while keeping everything balanced at full extension. The base station also needs to when fully collapsed fit underneath of the rover, as to not take up any extra space. It is to be contained below the chassis and between the six wheels. Another aspect that needs to be considered with the design of the base station is ventilation. It will contain multiple motors and other electronic components that need to be kept at a low enough temperature so as that they do not overheat causing failure or interruption of communications.

The type of router that the team plans on using is Cradlepoint industrial routers. Compared to standard routers these are very advanced

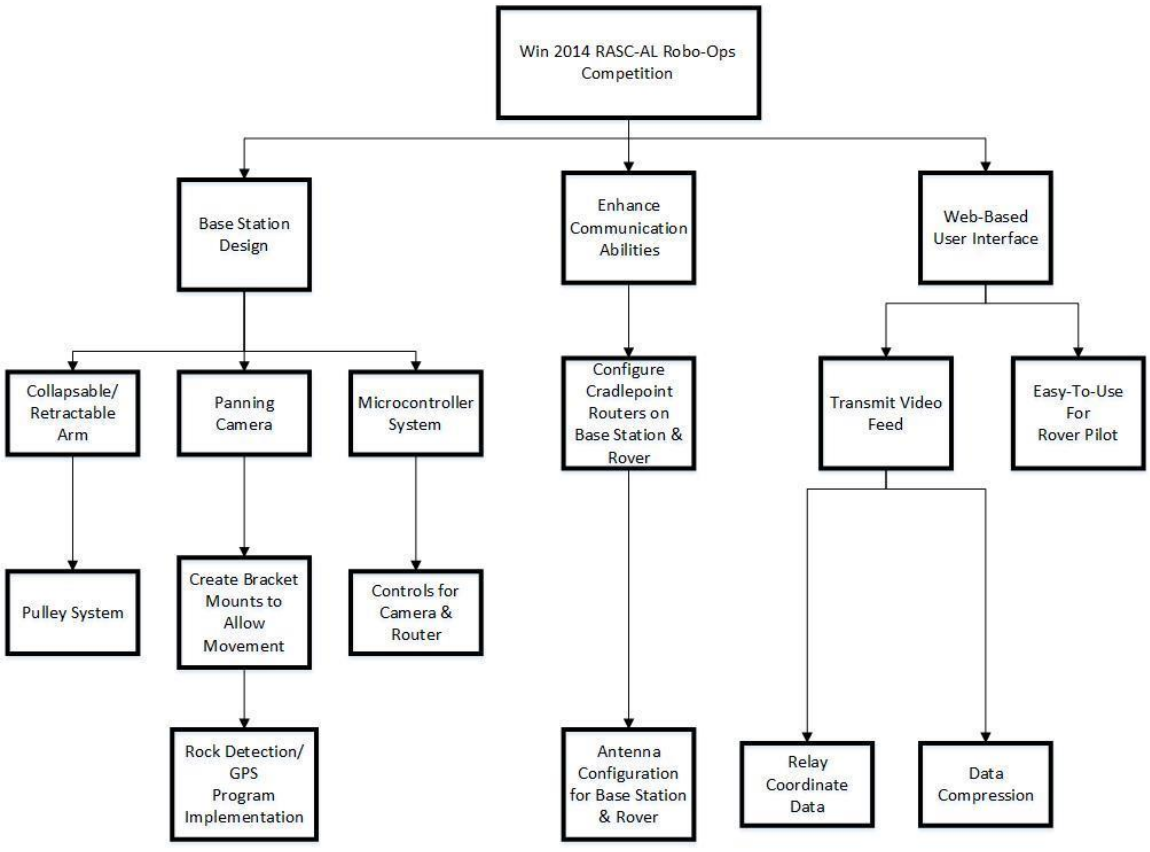
routers. They are one of few available that support a connection with cellular connectivity. Since a cellular connection is the most optimal way for communications to be relayed this is a very crucial point in the selection of routers.

In order to properly utilize these routers we plan to setup a VPN. This is needed to insure efficient communications between the two locations and the rover. In order for this

process to work the ports will need to be reconfigured in order to accept the incoming and outgoing signals.

The third major objective is to complete the GUI based program to integrate all of the incoming information that is being collected at the site in Houston. The purpose of this is to bring all of the information into one display including: all the camera feeds, the GPS location of the rover, and the GPS locations that are collected from the rock detection program. With all of this data plotted it puts the pilot at a great advantage allowing them to plot the best course throughout the field to best complete the task.

Objective Tree:



The objectives determined by the team. Objective tree designed by Chris Peyatt

Stakeholders:

The stakeholders for this project include the members of the WVU Robotics team, our faculty advisor Dr. Klink, the NASA West Virginia University Space Grant Consortium, and the Lane Department and West Virginia University.

The WVU Robotics team has been working to perfect this robot for the past two years. With the addition of the base station the team has hopes to advance in the competition. If our group fails at completing the tasks that have been set forth for us then it will be another year of disappointment for the team. If the base station is not designed, completed, and tested the team will be left no way to control the rover.

The Mars Rover has been under the direction of Dr. Klink since its start. He is not only in charge of the rover project but also the advising for all of the robotics team. It is his guidance that helps provide the team with the funding necessary to compete in these competitions. Without improvement in this year's RASC-AL competition WVU's participation may be in jeopardy for future years, having the robotics teams focus directed towards new projects.

The NASA West Virginia University Space Grant Consortium is responsible for a large part of the funds that have been invested into the WVU Robotics team. They have helped with fundraising, outreach, and NASA obligations. With the addition of the base station the team hopes to show this group the improvements that the team is working on and demonstrate the appreciation for the help received.

Winning this competition would be amazing publicity for the University and Department. This would attract prospective students interested in NASA and robotics. It would also attract new funding for any new

robotics related projects that WVU wishes to pursue. The more students and funding we get directed towards robotics at WVU will allow the university improve itself in the public's eye.

References:

"Mars Science Laboratory Telecommunications System Design- Article 14", DESCANSO Design and Performance Summary Series, Pasadena, California: Jet Propulsion Laboratory - NASA,

November 2009, retrieved 2012-08-07

Revolutionary Aerospace Systems Concepts-Academic Linkages (RASC-AL): System Level. Retrieved October 05, 2013 from RASC-AL: http://www.nianet.org/education/higher-education/rasc-al/

Individual Research Paper Mars Rover Project

Nathan Haney – EE 480

Needs:

The needs that are intended to be met by this year's Senior Design Team for the Mars Rover project are existing problems with the current design of the rover.

One of these needs is the creation of a base station that will be deployed by the rover for better visual and signal communication between the rover and the driver. The base station will be mounted below the Mars rover. Once the rover is placed on the starting hill area, the base station will automatically be deployed by the rover as is moves away from the station. The station will be extended to around 6 feet with a high resolution camera on the top to send video to the driver which will allow him/her to see a "birds-eye" view of the target area. The station will also act as a relay for communication with the rover. This will help with any "dead spots" and signal loss.

Another need for the Mars Rover is to make the system modular. This will help with maintenance for the rover as it will make specific components easier to remove then remount. These include the batteries as well as the motors on the rover.

Creating a virtual private network or VPN is also a priority need of the Mars Rover. This will be done by using a series of Cradle Points, commercial router, connected by a program in the pilot interface. The virtual private network will allow the pilot to connect to the Mars Rover by different routers in case one of them fails. This is why the Rover is planned to carry two Cradle Points. Having a Cradle Point on the base station will also allow the pilot to use its network in case of dead spaces. This is possible due to the fact that the base station should

always be able to keep a “line of sight” connection. If the signal power, line-of-sight, and the high data transfer rate from the base station is taken into account, then the problem of “dead spots” will be taken care of.

The last project that the Senior Design team needs to address on the Mars Rover is the pilot interface used to control the rover during the competition. The idea of the interface is to make it simpler for the pilot of the Rover to navigate through the terrain of the “Mar’s” like area. Several ideas are being decided upon. These include features that would display the multiple camera angles being provided by the Rover and the base station on one screen. The

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pilot could then choose which camera view he wished to use at the time to be present on the main controls screen. On the main controls screen would be a secondary set of directional buttons that the pilot could use with the mouse of a computer. The main screen would also house the secondary controls for the “claw”, arm used to pick up the designated rocks. These secondary controls would provide the pilot with an alternative in case a problem arose with the primary joystick during the competition.

Ranking Needs:

The largest priority for the Senior Design team working on the Mars Rover for WVU is creating a base station. The base station, as stated earlier, will be attached underneath the rover when placed in the starting area at the beginning of the competition. The base station will either be raised by the rover or will have motors attached to raise it to the 6 feet requirement.

After being capable of creating the base station and the extension of the base station to its max height, the ranking need would be to be able to relay the communications from the driver to the rover and in

reverse. This will be done by having a Cradle Point attached to the base station so that the possibility of a “loss of signal scenario” is minimized.

The next priority would be to create a VPN so that the Cradle Points within the rover and base station are connected and can be used by the driver to communicate with the Mars Rover. The idea is for the Rover to have two Cradle Points for redundancy in case one of the fails during the competition. The VPN will also allow the pilot of the rover to choose how to send communications to the rover.

The fourth level priority for the Mars Rover, would be the implementation of a new pilot interface. By creating a new interface for the pilot, the rover will be easier to handle and see the incoming data that the Mars Rover is sending back to the base station. This would include the ability to select the main view of the available camera angles. It would also house the secondary controls for the rover on the main screen in case there is a malfunction during the event with the primary controls.

The following priority for the Senior Design team would be to take existing components of the Mars Rover and combine them into a modular design. This will allow the team to take specific areas off the Rover for individual maintenance or upgrades. A few of the important areas would be the housing for the batteries and the legs that hold the motors for the wheels. This can be done by making box-like containers for the specific components that would be designed to fit in the areas they already use. The containers would be able to connect with the main frame of the Mars Rover. This also requires and upgrade and redesign of the cables and connects for the motors and batteries. The connectors would be made for quick connect and disconnect for easier access.

The lowest priority is to find a camera that is compatible with the communications system to mount on the base station. The camera

would be positioned at the top of the tower to give a “birds-eye” view of the competition area. Ideally, it would also be capable of rotating and tilting at the discretion of the driver so that he/she could zoom in on a specific area to validate the target rock without having to use time by moving the rover.

Background:

For the last two years, WVU has designed and created a Mars Rover to compete in the RASC-AL Exploration Robo-Ops Competition. The rover was designed to operate by remote control to find and collected specifically targeted rocks. During these two years, the WVU Mars Rover has placed fourth in the competition both times.

Last year, a problem that the team ran into was from the use of the camera that was mounted on the vertical stand on the rover. The camera was difficult to interface with their rock detection program. This problem was created due to the compatibility of the drivers used by the camera.

The RASC-AL Exploration Robo-Ops Competition is sponsored by NASA and the National Institute of Aerospace. It is for college level students and is meant to provide a competition for creating a prototype Mars Rover. The competition takes place at the NASA Johnson Space Center’s Rock Yard to create a realistic representation of the Mar’s terrain.

The Robo-Ops Steering Committee selects 8 teams from the applicants to bring their designs after creation to be tested at the competition. One part of each team will travel to NASA Johnson Space Center’s Rock Yard to perform on-site testing. The rest of the team will remain at WVU to participate as a “mission control” team. The “mission control” team is where the pilot is located which means the Rover is tele-operated. Several tasks are performed by the pilot such as upslope and downslope negotiation, capability of the Mars Rover to travel over sand

and gravel pits, identifying target rocks and the ability to retrieve them, and being able to traverse rocks of certain sizes.

The piloting of the Mars Rover must be done by commercial broadband wireless uplink. The only information that the “mission control” team is allowed is from the onboard cameras and other equipment located on the Rover.

The purpose of the RASC-AL Exploration Robo-Ops Competition is to include the public in NASA’s missions and research. The competition also requires a written report, a working Mars Rover model, and the ability to complete the tasks that are given by the judges. The scoring for the RASC-AL Exploration Robo-Ops Competition pertains to these tasks as well as weight and time requirements.

Objectives:

The objectives for the Mars Rover project are to create a base station, attach a camera and connect a cradle point to the base station, implement a new pilot interface, make the rover into a modular design, and to create a VPN type set up with the cradle points.

The base station will be design through Solid Works. The most likely design is to have the base station to be mounted on a plate that is the same dimension of the Mars Rover so that it can fit underneath. The tower of the base station will be laid horizontally under the rover and attached to the back of the rover by a rope or string. The tower will be hinged on the plate so

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that as the rover drives off the base station, the string will pull the tower vertical until it locks into place. Once locked into place, motors on the base of the station will turn on to raise the tower up to the designated 6 feet.

The tower will also house an antenna so that the cradle point can send

and receive signals from the rover. This will be done because last year there were occasion “dead-spots” in the target area. It will be used in conjunction with two cradle points that will be implemented within the Mars Rover. The idea behind having the tower act as a secondary control relay for the pilot and Mars Rover is so that at no point in time is the Rover without instructions from the pilot. If the main communications platform of the Mars Rover is unable to connect with the Rover due to a “dead-spot”, the pilot can switch over to relaying information to the base station which will then forward the instructions to the Rover. The Cradle Point on the base station will be capable of a strong enough signal output to reach anywhere in the target area that is in line of sight of the antenna on the base station. This method is not used as the primary means of communications due to some time lag that will be caused from the relaying of the signals through a separate router.

Objective Tree:

1) Design Base Station a. Decide whether Base Station extends under its own power or through the Rover

i. Connect cradle point with Base Station to relay and receive communications

1. Set up virtual private network with cradle points and pilot a. Connect new Cameras on the Base Station to the

communication network

. 2) Create new pilot interface

. 3) Semi-Redesign of Mars Rover

a. Decide which sections will be combined into a modular i. Change out certain wiring of components to help with easier docking

Objective Tree:

Decide General Dimensions of Base Station

Relaying Cradle Point Signal by Base Station

Connect Cameras To New Communications Newtwork

Create VPN for the connection of the Cradle Points

Create New Pilot Interface for Mars Rover

Semi Re-Design the Mars Rover

Decide Which Section will be Included in the Modular Design

Change Certain Wiring Connectors To Help with the Modular Design

References:

RASC-AL Exploration Robo-Ops Competition Website:

http://nia-cms.nianet.org/RoboOps/index.aspx

EE 480 "Mars Rover Redesign" Background Research Paper 10/14/2013 Christopher Peyatt

Executive Summary

The primary objective of this team's project, the Mars Rover Redesign, is to design, create, and test a working robot to compete in the 2014 RASC-AL Exploration Robo-Ops Competition. The robotics program at West Virginia University has competed in this competition in the previous two years, but has peaked with a fourth place finish. The team hopes to improve on this finishing position and win the competition with our design.

Aspects from previous robots will be used in our initial design. Lessons learned in each unsuccessful attempt at winning the competition will contribute to the knowledge base in which the team will meet design challenges. Our faculty sponsor, Dr. Klinkhachorn, has vast experience in building and designing to meet specific robotic functions and requirements. The team also is being aided by members of the robotic team, many of which have competed in this competition in previous years.

The main focus of the team's project will be to design a communications base station that will be placed at the starting point of the competition. This base station will use a camera, antennas, and a cellular communications router to locate scoring opportunities and our robot to communicate coordinates and other data to the robot. This will enable the pilots of the robot to have an easier time viewing and driving from remote locations, and it will equip them with more knowledge about the competition field and other surroundings.

By simply being accepted into the competition, the team will be generating $10,000 that will enable the robotics program to compete in competitions this year, as well as the future. Further money generated will depends on the work of our team, including placing in the competition, volunteer outreach, and working with corporate sponsors.

Components of our design have the potential to contribute in technological areas outside of robotics. This includes the communications overhaul that must be done to the robot. The competition requirements mandate that the robot, which will be in Houston, Texas, must be driven from the WVU campus. The improvements made in remote control can be applied in any semi-autonomous application, including the self-navigating vehicles that are currently being prototyped.

Needs

As of now, the Mars Rover Redesign will include improving the design of last year's competing robot. NASA officials informed the team that they did not want any aspect of the design changed, so we are keeping the basic design of the actual robot. However, this year the team will be supplementing the robot with a stationary base station that will be deployed with the robot during the competition. The base station will enhance communication systems on the robot and provide the team more information to make decisions with during the competition. The needs of this base station, as set by Dr. Klink, include a reinforcement of the entire communications network for the rover, a web-based graphical user interface (GUI), and support for the actual construction of the Mars Rover.

The communications for the rover has been a reason for some of the team's failures in previous competitions. The current system utilized a Verizon 4G cellular network that provides internet access to the robot so that video feeds and controls can be communicated between

Houston and Morgantown. This may be a great idea in theory, but the competition field features several “dead zones” and “lunar pits,” where the cellular signal cannot reach. By providing a base station with high gain and transmitting antennas, these areas will have cellular service in which the rover will still be able to communicate with the “home base” at WVU.

A web-based application will be developed for the benefit of the rover pilot that will be manning controls in Morgantown. In the past, commercial software was used that did not fully meet the needs and requirements for the team to effectively communicate and perform to its full capabilities. This application should include multiple viewing screens for separate cameras, a sonar-like GPS tracking system to keep track of the robot in the field, and the coordinates for scoring opportunities. A rock detection program will be written for the base station that will determine the areas within the field with the highest concentration of rocks, which must be collected in order to score points for the competition. The location of these clusters will also be displayed on the GPS sonar of the GUI.

While the base station serves as the main project for the senior design team, the team will also providing support in the designing and building of the Mars Rover. In the past, the last few components of the rover have been rushed to be completed in May, leaving little to no time for testing and contributing to failed attempts in the competition. By providing bodies for the team’s workforce, the rover should be done by mid-Spring. This will allow the senior design team to configure the rover’s end of the communications network and allow ample time for testing, modifications, and improvements.

Ranking of Needs

All of the needs listed above could be viewed as the biggest and most important aspect of the project. If the communications do not hold up,

the team is at risk to lose the competition. Without a user interface for the pilot, how could he or she maneuver the rover? If a finished robot is not complete in a short amount of time, the team will not be able to test the base station to ensure functionality, robustness, and convenience.

The number one priority for this project is to ensure that the communications network is vastly improved from previous competitions. A video can be viewed at the following website to show a glimpse of the troubles that were faced during the 2013 competition in regards to communications: http://www.ustream.tv/channel/wvu-mars-rover. As shown, it seems impossible to get a continual video feed of good quality. According to the pilots of the rover, the communications were solely responsible for WVU not winning last year's competition. By improving the quality of signal, the bandwidth and data rate can be improved for the link between the home base and the rover in Houston. This will allow for a better video signal that the pilots will use to drive the team to victory.

Obviously, an improved communications network will not mean anything if the pilots are unable to see where they are going or if they cannot find scoring opportunities in the field. This is where the GUI application will assist the team in reaching the goals that have been set. By providing multiple camera views, a GPS tracking system for the robot, and a rock detection system, the GUI will provide more information to the pilots and allow them to make better decisions and achieve a higher score for

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the team. The reason for this need being second, rather than first, is that the GUI will have no use if the communications are not established, and a backup is available in the form of the commercial software that has been used in the past.

Supporting the robotics team in building the robot not only shows the team's commitment to the success of the rover in the competition, but it also will give the team a better understanding of the internal components of the robot that will be useful when configuring the communications on-board

the rover. The team will need deep knowledge of the cameras and the computers used on the robot for the purposes of the GUI. There is only so much that can be learned by reading specifications and data sheets from the manufacturers. Providing the robotics team with a larger workforce to build the rover will result in a brisk pace and faster finishing dates. The sooner that the robot is fully functional, the quicker that both the robot and the base station can be tested and debugged.

Background

According to their website, the Revolutionary Aerospace Systems Concepts – Academic Linkages (RASC-AL) System Level Robotics Systems Competition (Robo-Ops) "focuses on a specific system in an interplanetary mission – robotics." The competition invites teams made up of undergraduate and graduate students to form a multidisciplinary team and build a "planetary rover prototype and demonstrate its capabilities to perform a series of tasks in field tests." These field tests take place at the NASA Johnson Space Center's Rock Yard, where teams must scour for brightly painted rocks that serve as scoring markers if the robot can collect the rocks and place them in an on-board bin.

Per the competition's rules, teams must operate the rovers remotely from the "mission control center" of their home universities. A small crew of team members are allowed to bring the rover to the Rock Yard and perform maintenance and modifications while on-site. The goal of the competition is to replicates the cooperation that must be present between robots and astronauts on future space exploration missions. The robot is not the only deliverable that teams must present to the competition judges. Each team is required to submit a technical paper, poster, and demonstrate an interactive Education and Public Outreach component that shows "participatory exploration approaches" for future NASA missions.

This will be the third year that West Virginia University has applied to compete in the RASC-AL Robo-Ops Competition. Each of the last two

years, the robotic team has finished in fourth place. A first place finishing position has been obtainable in both years, but mechanical and communication failures have hindered the success of the team in Houston. Dr. Klink is adamant that the team improves this trend, or WVU will not be present in future competitions.

In June 2012, the team had the heaviest robot of all of the teams, which according to the competition rules, meant that they had to go first. Without being able to see other teams navigate the course through a video stream (another competition rule), the rover became caught up in a "crater" in the Rock Yard. This situation had not been tested, so the pilots put the robot at maximum speed in an attempt to dislodge the robot. In doing so, the servos for the rear wheels became maxed out and began to malfunction. The robot was no longer operational, but enough rocks had been collected that the team secured fourth place.

This past June, the team made mechanical testing a priority to avoid a situation like the previous year. While the team still measured in with the heaviest robot and had to make its run first, a new "rocker-bogie" chassis allowed the robot to move in and out of craters and avoid getting stuck. This chassis design is based on the design of Curiosity, the actual NASA rover that has been traversing Mars since August 5, 2012. Even with the improved design and increased testing, issues were soon to arise. The on-board cameras (four total) were supposed to show a video feed at "home base," the robotics laboratory in the Engineering Research Building on the Evansdale Campus. The communications between the on-board computer and the station that had been set up here in Morgantown, that there was a twenty second lag in the video feed or sometimes the feed would go out completely. This made piloting the robot virtually impossible and, despite the improved mechanical design, WVU still only brought home fourth place.

This year, the team hopes to combine the improved chassis design with improved communications. The base station that the senior design

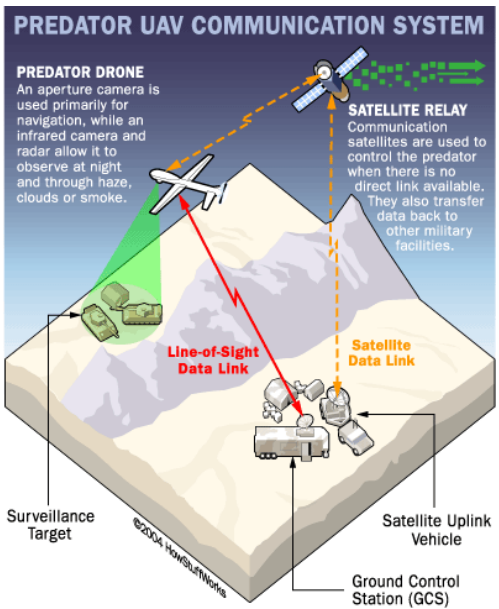
team will provide will give the robot more support while in the Rock Yard and allow for easier transmission of the video feed to Morgantown. A 3G/4G router will utilize a cellular data plan to compress the data and transmit

it to our laboratory. This added support will increase the bandwidth and speed of all of the data being sent and received between the robot, the base station, and our home computer.

The team is basing this idea on the communications taking place in current military applications. The Predator Unmanned Aerial Vehicle (UAV) is one of many new and proud innovations that the military is using for aid during warfare, recon, and scouting. The Predator can run autonomously or be controlled remotely, much like the rover that we will be building. The figure below gives a detailed breakdown of the communication system that links a pilot to the Predator. Since the team does not have the ability, or the funds, to purchase satellite space and exactly mimic the Predator, it has been decided that transferring the data through a cellular network would be the best solution.

Figure 1: Predator UAV Communication System

By deciding to use a cellular network to link the communication points, or nodes, the base station has the potential to be accepted and utilized by the general public. Any cellular telephone customer that has a data plan could purchase a similar base station for various uses. All robotic or Radio Control (RC) hobbyist could have the added dimension of long distance remote control. With further development, which would not be included in the scope of this project, a mobile app or web interface could be developed for ease of use and marketability.


PREDATOR UAV COMMUNICATION SYSTEM
PREDATOR DRONE
An aperture camera is used primarily for navigation, while an infrared camera and radar allow it to observe at night and through haze, clouds or smoke.
SATELLITE RELAY
Communication satellites are used to control the predator when there is no direct link available. They also transfer data back to other military facilities.
Line-of-Sight Data Link
Satellite Data Link
Surveillance Target
©2004 HowStuffWorks
Satellite Uplink Vehicle
Ground Control Station (GCS)

Taking this idea a step further, remote control has unlimited potential to be useful in the automobile, railroad, and airline industries.

Objectives

Each of the needs for the project, which were described in the earlier section, can be broken into separate objectives. The highest objective that this team will attempt to meet is to win the RASC-AL Robo-Ops Competition. This would verify and reinforce all of the hard work of this senior design team, the robotics team, and Dr. Klink. A win would boost the reputation of West Virginia University's engineering program and continue the trend of excellence that has been exhibited by the robotics program.

As for the design itself, the base station can be broken down into three overarching objectives that can be separated. Our first is physical design of the base station, including the collapsible arm that will support the camera and cellular antennas. The aspects of the arm that will serve as the objectives include configuring the motors of the arm, designing the arm so that it can both collapse and extend at least two meters above the ground, and providing a platform the will support and rotate the camera. All of these sub-objectives will contribute to a successful arm, which is essential to the success and usefulness of the base station. For the body, or base, of the base station, several objectives must be met for this project to succeed. To begin with, the team must get creative to map out the electrical system and all motors so that it will fit in the confined space that has been allotted for the fully collapsed base station. The base must also provide some sort of ventilation so that the minimum peak temperature among the electronics is not reached. Lastly, the cellular network router must be able to receive and transmit at an optimal signal to ensure the highest quality communications.

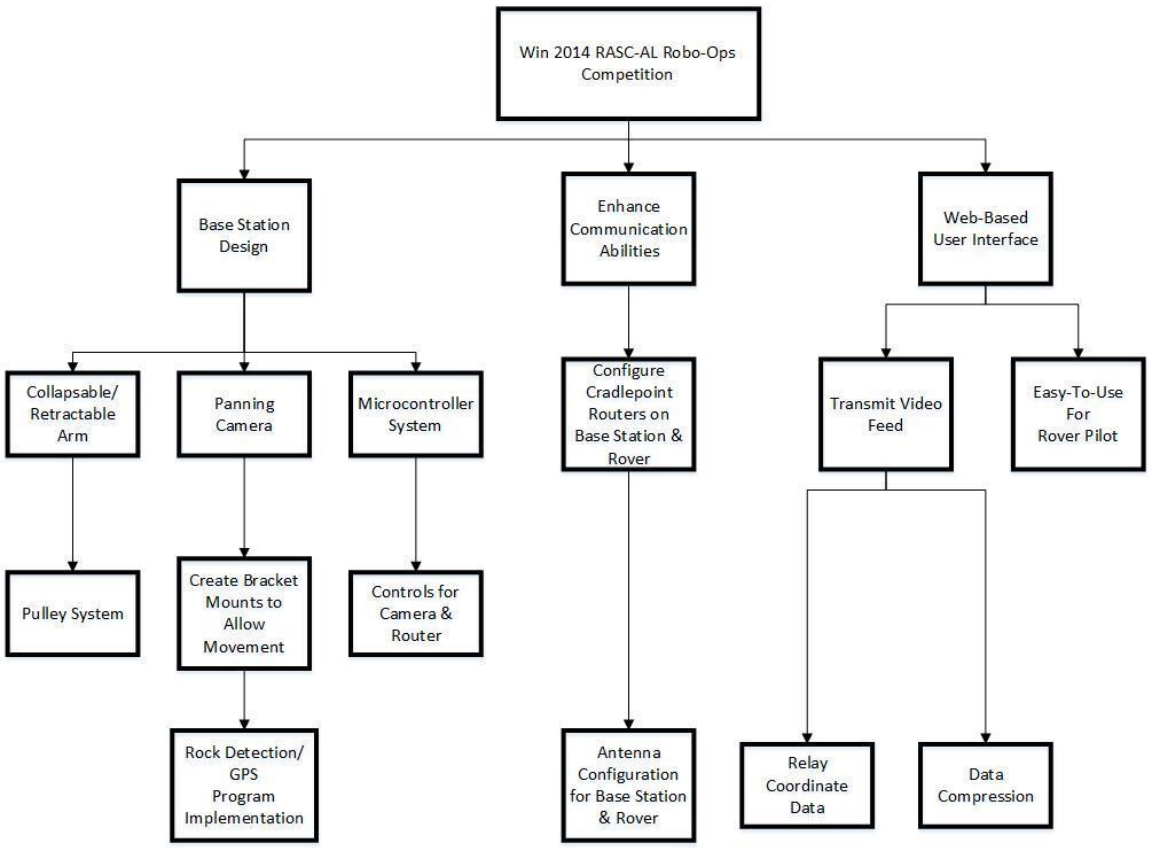
Most of the communications will be done through Cradlepoint

industrial routers. These high-tech routers are one of the few in the field that support cellular connectivity, which is a key design component for the team. Our objective, as it pertains to these routers, is to configure them to meet our needs. A VPN will be configured to ensure high speed data

transmission between the base station, the rover, and the LCSEE servers on the WVU campus. To enable the VPN on the routers, all ports will be reconfigured to accept incoming and outgoing connections. Also, the team will design two sectorized antennas that will be placed on the base station and the robot. Using the GPS tracking system, the antennas will move correspondingly to provide the highest signal strength at all points of the competition field. This should prevent service being lost due to the “lunar pits,” as in previous years.

Lastly, the web application GUI must be developed so that it is easy-to-use for the pilots of the rover. By keeping the controls and interface simple, the pilots will be able to focus their full attention on achieving the best score possible during the competition. The initial design calls for four separate camera viewing windows so that all angles of the robot and the field of view is always observable. In order to handle all of the bandwidth required to transmit simultaneous video feeds, all of the data must be compressed from the camera before it is transmitted over the network. The packets of data will then be decompressed at WVU on the home servers. The GPS data will display the location of the rover, in reference to the rest of the Rock Yard, on a sonar style display. The GPS coordinates of the detected rock clusters will be displayed on the sonar giving the pilots multiple options for the best possible path.

Objective Tree



Stakeholders

The main group of stakeholders for this project are the members of the WVU Robotics team. They are helping the group construct the rover in parallel to the team building the base station. If the base station does not work properly, the work that has been done year round will be jeopardized and the communications system will have to be redesigned in an unrealistic time frame.

The second stakeholder in our project is Dr. Klink. He is not only the faculty advisor for this project, but Dr. Klink is also responsible for advising and maintaining the robotics club. He is in charge of all finances for our project and the robotics club while also determining which competitions and projects WVU should be entered in. Dr. Klink has expressed his concern for future RASC-AL competitions, and has informed the team that another fourth place finish may mean that WVU will no longer invest in the rover robots.

Another stakeholder in this project is the NASA West Virginia University Space Grant Consortium. This group has invested a large amount of funds and countless hours into helping the robotics team with fundraising, outreach, and NASA obligations. It would be ideal for the base station to aid the robotics team and return the Space Grant Consortium investments with a win in the competition.

The last, and probably the most obvious, stakeholder in the success of the group's design is the Lane Department of Computer Science (LCSEE) and West Virginia University as a whole. If the team is able to finish the competition in first place, it not only will reaffirm the reputation of the department and the robotics program, but it will also give good publicity and outreach on the school's behalf. Prospective students interested in Electrical, Computer, or Mechanical Engineering, or even if it is just an interest in robotics, will know that WVU and the LCSEE provide an opportunity to learn and participate in programs that rival any engineering program in the country.

All stakeholders in this project have the same goal: to win the 2014 RASC-AL Robo-Ops Competition. By winning the competition, the senior design team will generate revenue for the organization, provide reasons for the robotics team to continue to participate in this competition, and reinforce the reputation that WVU robotics has developed over the course of just a few years.

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Mars Rover Draft

Wei-Ting Chang

EE 480 2013/10/14

Needs

The senior design group is now part of the West Virginia University (WVU) Robotics team which competes in the RASC-AL Exploration Robo Ops competition sponsored by NASA in Houston. The Mars Rover was already built, but some major problems were found during the competition last year and the rover is currently redesigned and rebuilt. The major problems that the team encountered were mostly due to the communication system, which included the video feeds sent from Houston to WVU and the communication between the robot and the pilot. Also, some other parts needed to be improved are the extension arm on the rover, the battery system and the weight of the rover.

In the competition last year, WVU team was far behind the schedule. The communication system and some other components of the rover were not fully tested. During the competition, the problems on the communication system came out. The pilot who was at WVU trying to control the rover could not receive smooth video feeds from the camera on the rover. The video had a seriously delayed so that it not only made navigating the rover much more difficult, but also made it harder to find the targets. The improvement on the video quality can help the pilot to finish tasks in limited time.

The solution for most of communication problems the team encounter last year is to build a base station that will not be moving during the competition after it is deployed. The base station has to meet couple criteria in order to be used in the competition. First, it has to fit under the Mars Rover. It

cannot exceed certain dimension. Second, it can extend itself toward the sky until it is two meters in height. Third, a camera should be installed on the top to help pilot locates the rover and the target. The last thing will be the weight. The base station will be used to improve the communication between pilot and rover.

The software on the computer on the rover needs to be modified. A Virtual Private Network needs to be setup between the computer at WVU that is used for navigating the rover, the base station and the rover itself. The tests on the performance of VPN and actual communications between pilot, base station and the rover have to be tested again and again. The extension arm on the rover was made

in a rush so the quality and functionality both need to be improved. The arm needs to selectively pick up the target with various irregular dimensions and weights.

The weight is one of the most important limits in the competition. The older version rover had a battery for each individual motor for each wheel. The redesigned rover will have just one main battery. The replacement of the battery system will not only reduce the weight of the rover, but also reduce the difficulty the team encountered that charging each individual battery has.

Ranking of Needs

The communication problems are definitely the first thing that the team should solve. From the competition video last year, it is clear that the pilot had trouble to efficiently navigate the rover and finish the tasks in very limited time. The situation was that the video delayed about five to ten seconds after each movement the pilot made. If this could be solved, the pilot will have enough time to locate where the rover is on the field, identify the targets quickly, navigate it to the target and finish the missions.

The second need that should be accomplished is to design and build the base station. The base station will be used to help solve the communication problems while the rover is at the location where the reception is not well.

In this case, the base station will be used as a relay station. Also, the camera on the base station will be used to assist locating the rover and the targets.

Weight should be the next thing to focus on. The lighter the rover is, the more efficient the energy could be. While changing the battery system will reduce the amount of batteries, the battery life could be affected. The motor will consume less energy to go same amount of distance and it could last longer. The other reason that the weight is important is that overweight will lead to penalty.

The extension arm is less concentrated on because it is currently functioning. Due to the fact that the arm was made in a hurry, an improved and well-made version should be built to make sure it could accurately pick up the targets with various sizes and weights. Last thing that needs to be completed is to fully test all components and check if there is anything else that does not meet the expectation.

Background

The RASC-AL Robo Ops Mars Rover competition is held in Houston, Texas every year. 2014 will be the third year that WVU participates in. The first two years, WVU Mars Rover team did not do as well as expectation. Some problems were mentioned earlier in the paper. This part of the paper will explain what the competition is like, what criteria a rover needs to match and the ideas of how the team is going to achieve those needs.

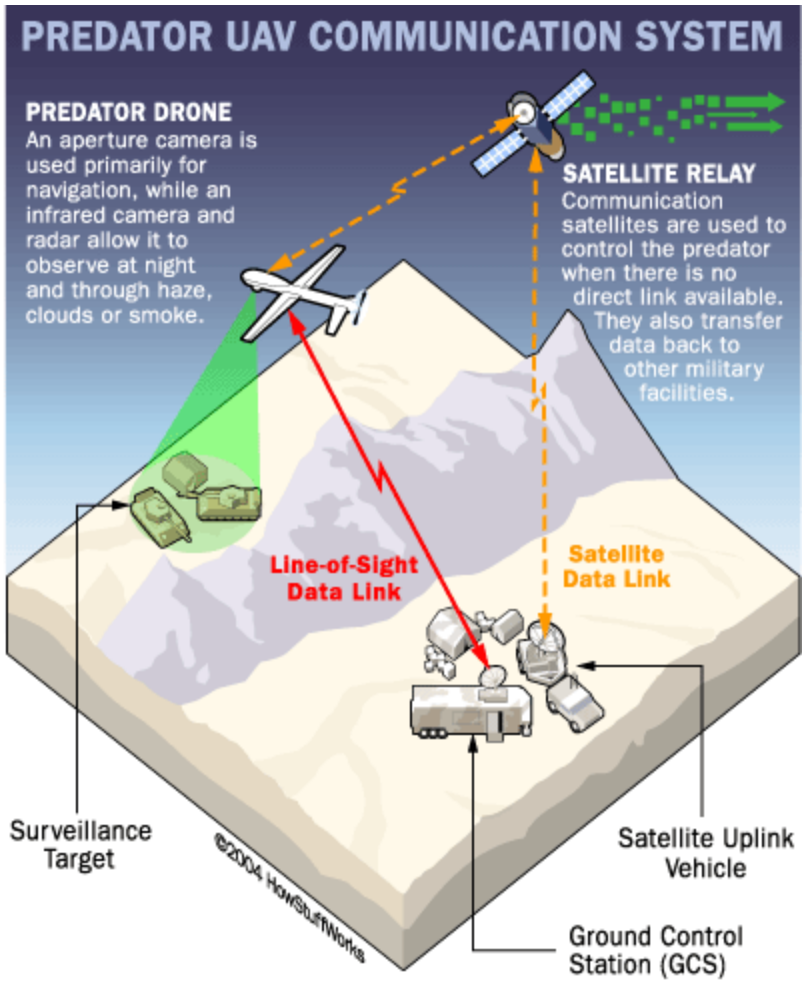
The rover cannot exceed 1m x 1m x 0.5m in dimension and cannot weigh more than 45kg in total. Add-ons are included in the dimension and weight limit. The rover should be able to traverse various surfaces. It could be sand or rock. The courses might include different slopes hills. The rover should also be able to negotiate with upslopes and downslopes. After unpack the rover and necessary adjustment, the add-ons or other attachments that wish to be used in the competition must deploy themselves. More important thing is the rover has to be able to distinguish colors.

The goal of the competition is to move around in the different areas and try to find the target rocks. The target rocks will be in different color. There will

be 6 different color rocks (red, purple, blue, green, yellow and orange) with total minimum amount of 30 colored rocks for each team to collect. Each color rock is assigned to different point value. Each team has to pick up the colored rock and store it by the rover within one hour long course. The final score depends on how many colored rocks the rover brings back and how many points each color worth.

The topography of the competition will look like the figure below. It will include Rock Field, Lunar Craters, Sand Dunes and the Mars Hill. The Gravel pit will not be used in this competition. The team will start the competition on the top of the Mars Hill.

As mentioned earlier, to win this competition, there are many things that need to be improved. First of all, the communication problem could be solved by building an extra base station with camera on it. The base station will be attached to the bottom of the rover. Once the competition starts, the rover will start on the top of the Mars Hill. The rover will release the base station and start moving toward the bottom of the hill. At the same time, the base station should start extending its antenna to two meters tall. The camera on the top of the antenna will help locate the rover and targets. The base station will not move during the competition. The purpose of doing this is to use the base station to enhance the signals in that area. It will be used as a relay station between pilot and the rover. The concept behind this is very similar to the Predator UAV shown in the figure below. While direct connection is available, the direct connection will be the priority. When the rover enters the area that cellular signals cannot reach, the base station will act like the satellite in the figure.


PREDATOR UAV COMMUNICATION SYSTEM
PREDATOR DRONE
An aperture camera is used primarily for navigation, while an infrared camera and radar allow it to observe at night and through haze, clouds or smoke.
SATELLITE RELAY
Communication satellites are used to control the predator when there is no direct link available. They also transfer data back to other military facilities.
Line-of-Sight Data Link
Satellite Data Link
Surveillance Target
Satellite Uplink Vehicle
Ground Control Station (GCS)
©2004 HowStuffWorks

Both the rover and the base station use the cellular data to connect to the internet and VPN. The base station can also transmit and receive data via WIFI to communicate with the rover.

The actual design of the base station is still under discussion. The extension pole needs to extend to two meters tall toward the sky. How to let the pole extend itself without human interference is still under discussion. One of the ideas is that when the rover leaves the hill, a string attached on the rover could pull the pole toward sky with some trick. Spring is also considered. No matter which case, light weight material must be used, but it has to be strong enough to support the antenna and the camera on the top. The wind should also be taken into account. The camera on the top will rotate and look around the field so a motor needs to be installed on the pole. This will soon be decided and built by the team.

Since the add-on base station will be included in the weight limit, the weight of base station must be carefully controlled.

The software has to be modified because an additional base station is used. The VPN has to be setup. A VPN can create a private network through the public network. Any user outside of the private network could not obtain the information in the private network. All data transmitted in the VPN will be encrypted. It could be setup by using the built in software in Windows 7.

The configuration needs to match between the computer at WVU, base station and the rover. Once it is setup, the performance needs to be optimized.

Objectives

The main objective is to win the competition, but to win the competition; two major objectives need to be achieved. Due to the topography, some areas might have difficulty getting cellular signals directly so the rover could not receive any signal/instruction from the pilot. A relay station can help transmit and receive information between the pilot and the rover. While the rover lost the connection to the internet through cellular network, the base station will receive the information from the pilot and then send to the rover via WIFI. Therefore, a base station on the top of the hill with two meter extension should be able to help improving the communication.

The location is another key to win the competition besides the communication part. Knowing where the rover and the targets are all the time will definitely help the team finish the mission in limited time. The camera on the top of the base station pole can be used to locate the rover and the targets. It provides a clearer view of the areas. The combination of first person view and third person view can reduce the time pilot needs to navigate the rover.

Objective Tree

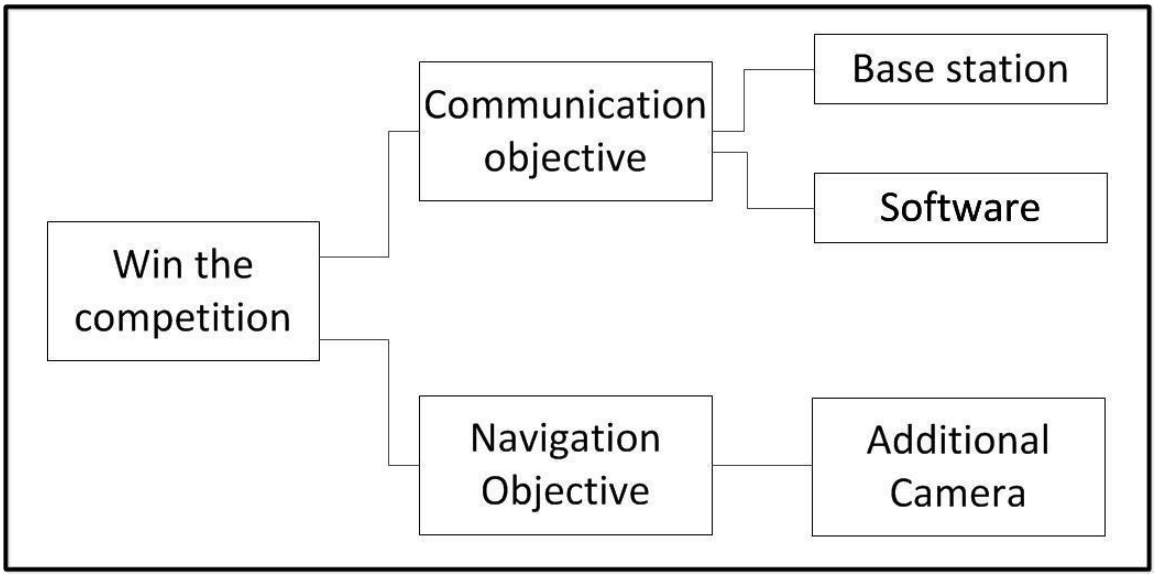
Stakeholders

Robotics team will be one of the stakeholders of this project. If the base station could work as expected, they will be able to solve the long last communication problem. Hopefully, they could win the competition because of this.

NASA West Virginia Space Grant Consortium will be another stakeholder of this project. NASA is sponsored the competition. Their goal is “to engage as many people as possible in space exploration missions”. They help Robotics team raise funds.

Dr. Klink is also the stakeholder of this project. He is the faculty adviser of the robotics team. He spent a lot of his time to help and instruct the team. He is now also the faculty adviser for the senior design group. The success of the team is what he wants the most.

West Virginia University will be another stakeholder for this project. The main goals of WVU are to train the students and win the competition. They invest the robotics team. If the team wins the competition, they are also the one who can get most benefited from it. The reputation of WVU will be



good and might be able to get more attention and funds from other organization. More students who are interested in this area will apply WVU.

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Mars Rover Base Station

Individual Research Paper

Zak Hooper

Introduction This project originates from the RASC-AL Exploration Robo-ops competition. West

Virginia has competed in the competition the last few years but has not yet placed in the top few. This is partially due to the communication feed back to the person controlling the rover. The video feed was very jumpy and made the rover very difficult to control. With this project, there will be a base station that will keep internet connection to the rover at all times and also have a third person view of the rover to help navigate on the Rock Yard. Pictured below is a picture of the old WVU Mars Rover. With this project the rover will start out with a base station underneath. Then when starting the competition the base station will be deployed on the top of Mars Hill.

Competition The RASC-AL Exploration Robo-ops competition is an engineering competition

sponsored by NASA where teams compete to build a planetary rover and demonstrate its

capabilities in the NASA Johnson Space Center's Rock Yard. Up to eight teams are selected to compete. Up to three team members and a faculty advisor will travel to Huston with the rover for the on-site testing. The remaining of the team members will stay behind at their university and complete mission control objectives. The rover will be tele-operated from campus to complete various tasks. Some of the tasks include navigating obstacles, collecting specific rock samples and storing them on the rover, driving over rocks of certain size, and driving through sand and gravel pits. The rover is required to be controlled on the university campus via commercial broadband wireless uplink. On-board camera and sensor feed will be send back to the university as well as to the general public. All teams participating in the competition must submit a written report, build an actual rover, and demonstrate the rover's capabilities in Huston during the 2014 RASC-AL Robo-Ops Competition. Below is a Google Earth picture of the NASA Johnson Space Center's Rock Yard. The rover should be able to navigate Mars Hill, Lunar Craters, the Rock Field, and the Sand Dunes. The Gravel Pit

will not be used in this competition and the Sand Dunes will be weeded and be solely sand. Each team has one hour to complete the course. A minimum of 30 rock samples will be scattered throughout the course to be collected. Bonus point will be awarded for returning the rocks to the top of Mars Hill, for collecting one of each colored rock from each terrain, and for collecting an "alien life-form."

Problem Statement In previous year in the RASC-AL Exploration Robo-ops competition the video feed back

the university's campus has been jumpy and very hard to see in real time what was actually happening in Huston. This project hopes to add a base station that starts under the rover and deploys at the top of the hill. This base station should help with communications and give a third person view of the rover in the Rock Yard.

Objectives The primary objective of this project is to improve the video feed back to campus from

Huston. Do accomplish this a base station will be deploy at the top of the Rock Yard. This base station will be equipped with a wireless 4G LTE connection. Due to the location of the base station, it should always have cell service. This base station will be able to communicate with the rover and even when the rover goes into a dead zone it will still be connected to the network. To help with network connection, CradlePoint is going to be used to provide 4G service. CradlePoint is a 4G/3G network router solution to providing business grade, secure connectivity from 4G and 3G networks.

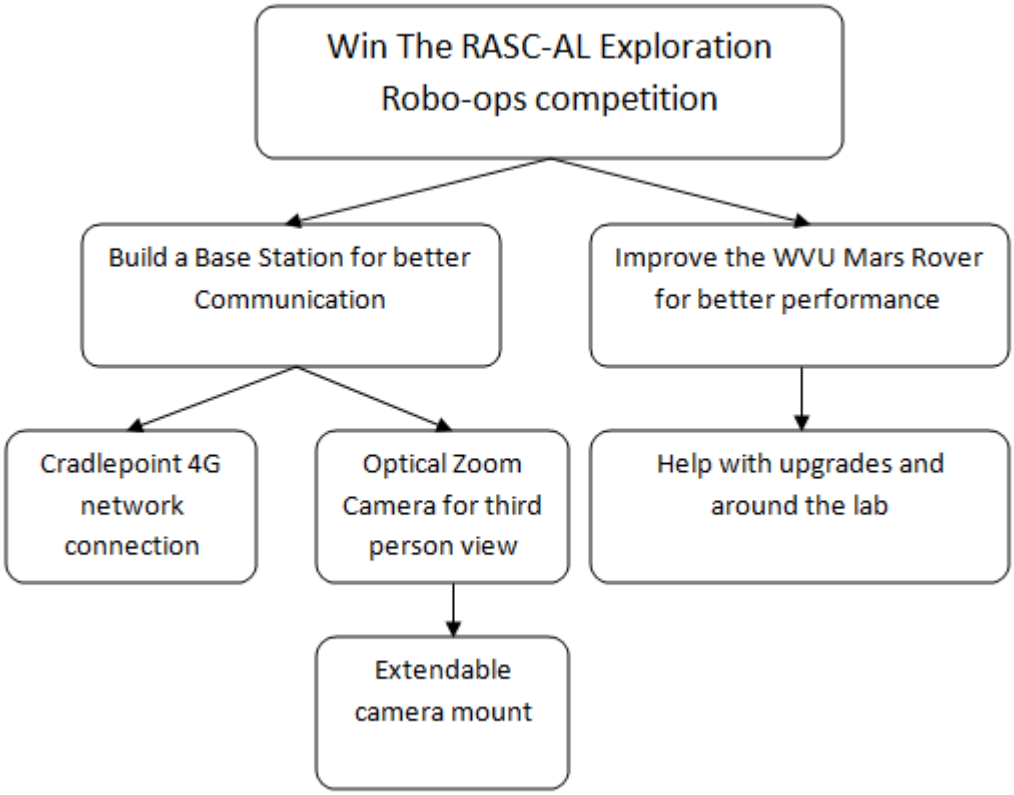
To improve the field of view for the competition, the base station will also be equipped with a camera with optical zoom. This camera will give a third person view of the rover and will also be programmed with color detection algorithm to help locate the colored rocks. This camera will allow for easy location on the Rock Yard and help with the position of the rover. The camera will also be able to pinpoint locations of the colored rocks and communicate with the rover to collect and store the rocks.

To give the camera a better field of view, the camera will be mounted on a extendable pole to raise the camera into the air. The base station will start out under the rover and be deployed on the hill. Once deployed, the camera pole will be laying down on its side and will rise up into a vertical position. Once the pole is completely vertical it will begin to rise up to the specified height.

Objective Tree

Stakeholders The stakeholders in this project are West Virginia University Robotics and NASA stakeholders.

WVU robotics hopes to finally win the RASC-AL Exploration Robo-ops competition. NASA wishes to engage as many people as possible into this competition to get people interested in space exploration. In the overall score of the competition there is a section to get 5 points for a team blog or social media page. This social media page is to get the general public interested in space exploration along with helping with their outreach program.


Win The RASC-AL Exploration Robo-ops competition
Build a Base Station for better Communication
Improve the WVU Mars Rover for better performance
Cradlepoint 4G network connection
Optical Zoom Camera for third person view
Help with upgrades and around the lab
Extendable camera mount

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Rylan Maynard

EE 480-Senior Design Seminar Research Paper Due: 10/14/2013

Introduction:

For my senior design project I chose to work with the WVU Robotics Club under the supervision of Dr. Klinkhachorn. The particular project I am working on is the redesign of the Mars rover. The past few years West Virginia University has had the honor of competing in the Rascal Robo-Ops Mars Rover Competition as well as the NASA Robotic

Mining Competition. In the past few years of the Mars Rover Competition the WVU robot has finished 4th out of 8 competing universities. The ultimate goal of our senior design group is to build upon the robots strengths and redesign to fix the weakness so that WVU can improve our finish.

Along with redesigning the robot this year our senior design group will also design and build a new communications base station. This will be a new approach that we feel will greatly improve our chances of winning. Integrating the communication systems of the robot and the base station will be both challenging and rewarding. Given our clear image of what we want to achieve along with the skills and abilities of our group, we feel certain we can achieve our goals.

Needs and Relevance:

In recent years the advancement in electronics and development of more power efficient circuits, advancements in devices that mix mechanical jobs with electrical means. According to Webster's dictionary a robot is a device or machine that automatically performs complicated often repetitive task in the place of humans, controlled by a computer. Popular to contrary believe even though it seems that robots are a new idea they have been thought about and imagined even as far back as the Greco empire. It wasn't until the 1960's that robots were

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introduced into industry revolutionizing assembly and manufacturing. Since their integration into industry robots have only been further researched and advanced an used in many new areas of both the government and private sectors.

With the evolution of the internet, satellites, and high speed data transmission the need to control devices remotely grew. There are many such devices in use today such as predator drones and bomb disarming robots. The robot we are working on both needs to receive and transmit data at a high rate over extreme distances. It also must also be able to achieve mechanical purposes.

Our Mars rover won't generate any stock holders or have any impact as far as taking a product to market. On the other hand the research and development that goes into building our rover could be used in private sector businesses. The same technology that we use for our robot could be put towards automated cars and even automated construction equipment. The limits of where you could push the technology that we develop is truly non existent.

Ranking of Needs:

First and for most for us to succeed we must achieve designing and building a communication base station so that our rover will never be without a signal to receive and transmit data. Then we will develop a user interface to control the rover via a web browser. While these will be the the main objectives that we spend our time on, our group will work tirelessly with the Robotics Club to support them in any capacity we can. Primarily we will be tasked with fabricating and and assembling any devices and furthering help the overall design of the robot become lighter.

For the base station we will be using Verizon 4G cellular networking over a VPN network. In years past the downfall of the University's robot has been failures in communications. We are hoping that using our new and improved base station idea we will be able to over come our failings in the past.

We believe that using our secure VPN in relation with a web based interface, a GUI, will be the best approach. Using this interface with the network we create will allow you to connect to the robot and control it. There will be sensors for positioning and and a video feed that will need to be transmitted from the rover back to "mission control" in Morgantown.

Lastly the rules of the competition give a bonus to lightest the rovers in order, therefore in the redesign efforts we will be looking for ways to shed some weight. Along with shedding weight we are going to make it

our goal to finish construction of the rover with plenty of time to test out all of our modifications. This has been a problem in the past but we are going to see to that we do not encounter this again.

Background:

The WVU Robotics club has participated in the the RASC-AL's ,which is short for "Revolutionary Aerospace Systems Concepts-Academic Linkage", Robo-Ops. The competition involves teams designing rovers that are specifically used for planetary exploration and discovery. The competition is funded and overseen by NASA and takes place at Johnson Space Center's Rock Yard in Houston Texas. The competition calls for more than just a rover we must also provide a a technical paper describing our rover's operations, a poster for aiding in presentations, and lastly submit a plan for public outreach and interactive learning for future generations.

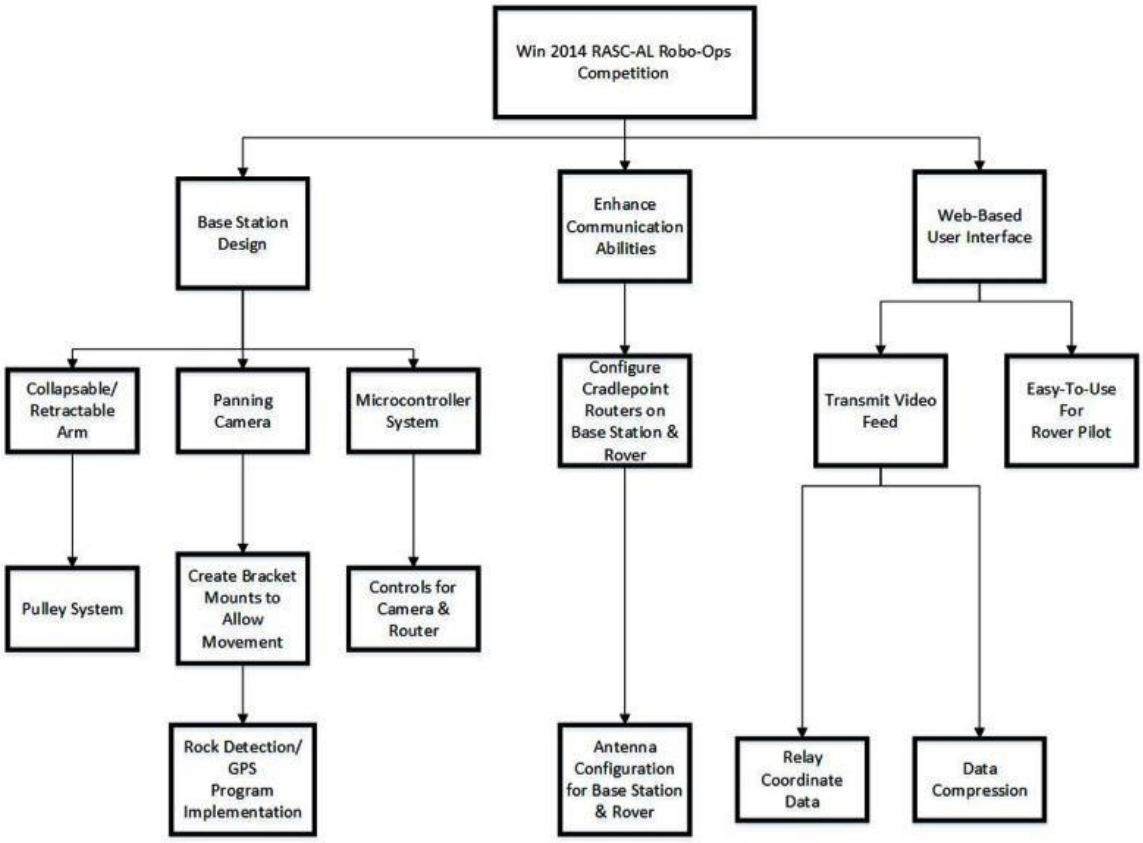
West Virginia University will be competing for the third consecutive year this spring. In the past we have only received the rank of fourth place. Though it is commendable we expect better of ourselves as does Dr. Klinkhachorn. He has given us an ultimatum to improve our finish this year or we will not present in the future. The Robotics club has learned from the past few years in competition and has improved the chassis design and we are hoping that improving the communications system will be the edge we need to advance our position.

Objectives:

The prime objective is to claim a win for WVU at the RASC-AL Robo-Op. The main objective can be broken down into a few smaller goals. First will be the design and construction of the base station. Along with the base station there will be design and laying out of the new communication systems utilizing Cradlepoint routers. Another objective is our design team will implement an antenna system for both the base station as well as the rover that allows the antennas to move into position to ensure the strongest signal strength. Lastly our design team will be

tasked will making and operating a web interface. This is the same interface mentioned above that will be utilized to operate the rover remotely. The VPN connections we create will allow for our communication networks to transmit the data back forth from our computer at "mission control" and the rover in Houston.

Objective Tree:



*Objective Tree by Christopher Peyatt

Stakeholders:

Currently the parties with most on the line is the WVU Robotics Club. As mentioned before the current project we have is not one that could be used in the private sector or have a product taken to market directly. However moving forward many of the ideas that we are using and further in our design process could be used in the future for many different industries. There is a viable need and use for remotely

controlled devices over long distances. Imagine the ability

to control construction equipment off site remotely eliminating the risk of human harm on the job site.

References:

- RASC-AL Exploration Website:

http://nia-cms.nianet.org/RoboOps/index.aspx

- Relevant Cradlepoint Technology
http://www.cradlepoint.com/products/branch-office-retail-pos/arc-mbr1400- series-with-integrated-3g-4g

- History of Robots in Industry
http://spectrum.ieee.org/automaton/robotics/industrial-robots/george-devol-a-life- devoted-to-invention-and-robots

Appendix 4 - Summary of Implemented Changes

- **Separate Enclosure**: Originally, the battery, CradlePoint, and Raspberry Pi were to be contained in a rectangular enclosure that would also serve as the hinge for the mast. After many design changes and optimizations, a separate aluminum enclosure was constructed to hold the battery and raspberry pi, with the CradlePoint mounted on top of the enclosure. The pivot point for the mast is now a separate component of the system.

- **Smaller Battery:** A thinner battery was found that provided 3,000 more mAh while saving in weight, so this was used rather than a bulkier 5,000 mAh 5 Cell LiPo battery as originally planned.

- **Software:** The networking camera that was purchased by the Robotics team, a Panosonic iPro WV-SC386, had built in compression and streaming software. The API for this software fit the description of what was needed, passed all bandwidth tests, and was user-friendly. This eliminated the need for the group to develop original software for the Axis IP camera that the group initially intended on using.

- **Carbon Board Platform**: The enclosure and mast will sit on a carbon board platform that extends the length of the rover. The platform is thinner in the middle, with extra width added on each end. The extra width on each end matches the width of the rover's wheels. The cylinder will extend the mast when the rover's rear wheels are sitting on the far end of the platform. This is aimed to keep the center of gravity of the system as low as possible to prevent the system from tipping. Originally, the system was designed to include a 2x4 board, with the only purpose of mounting the cylinder. This was a heavier design, and did not provide enough stability.

- **Raspberry Pi Externals:** After experiencing some troubles, and injuries, while attempting to get the pressure high enough in the cylinder to both extend the mast, and raise the upper section, the group decided it would be best to sacrifice some weight and include a DC motor, solenoid, and three limit switches. This added, in total, less than 0.3 kg, but made the construction more fail-proof and simpler.